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MILK PRODUCTION AND PROCESSING

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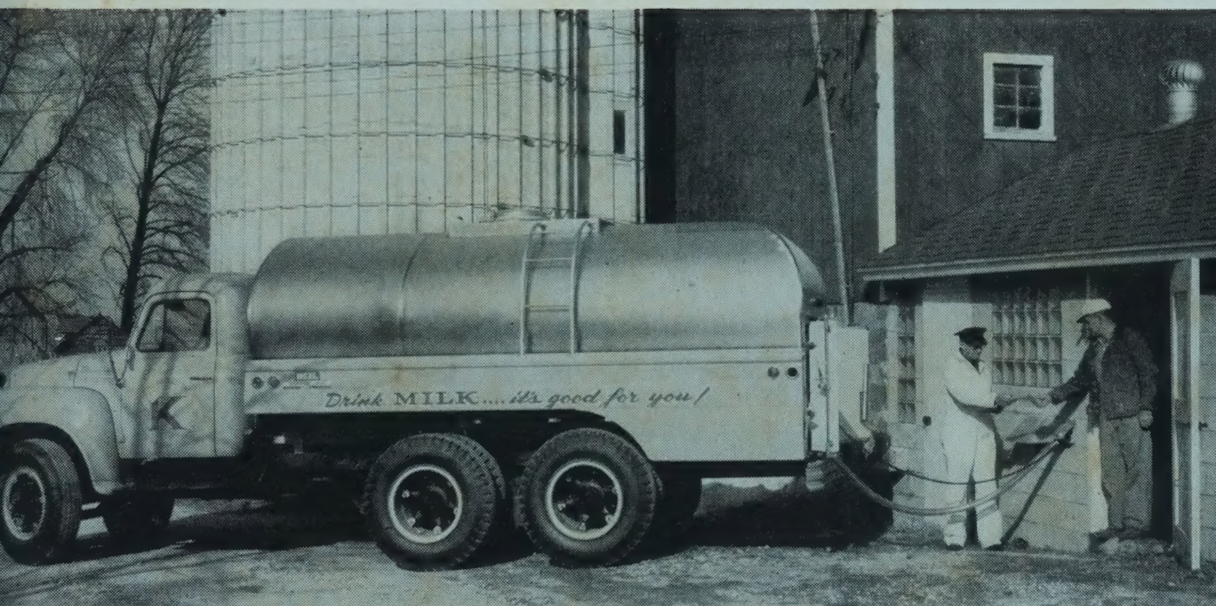
MILK PRODUCTION



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Milk production...

Preface

There are few types of agriculture in which the dairy cow is not of considerable importance. The processing and sale of milk and its products have developed into a big industry with more opportunities for men trained in dairying than there are graduates available. Most colleges of agriculture require an orientation course in dairying for most or all of their students. This practice insures that graduates who go into various phases of agricultural production will have at least a general knowledge of the dairy industry. Such a course also serves as a prerequisite for more advanced work in dairy science. This type of course is generally broad enough to indicate the opportunities in the dairy field, but still informative enough to be of use to the student who never takes another dairy course.

Most schools include both milk production and milk processing in the orientation course. Some stress certain phases more than others. A few schools have elementary courses which cover only the properties of milk and its testing, handling, and processing. We have prepared this book as a textbook for any of these elementary courses. Many secondary schools offering agricultural subjects also will find that this book fits the needs of a general course in dairying.

We have arranged the chapters in what is felt to be the most logical approach to an orientation course. In each chapter, however, we deal with a specific subject, which makes the book adaptable to the ideas of presentation of the individual teacher. Our plan has been to present the general scope of the industry—the essentials of successful dairy farm operation, the composition of milk and its secretion, the essentials of herd management, the testing of milk for chemical and

sanitary quality, the processing of various dairy products, and an examination of the nutritive value of dairy products.

We feel that the questions at the end of each chapter will be helpful to student and teacher alike. Since arithmetic plays an important part in any successful dairy operation, practical problems will be found at the end of several chapters.

The material that we might have placed in the appendix is unlimited. We have chosen to include items which we feel will be most helpful.

Finally, the authors would like to thank the many individuals, associations, and companies that have provided advice, technical information, and illustrations.

HENRY F. JUDKINS
HARRY A. KEENER

White Plains, New York
March, 1960

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APPENDIX

CHAPTER 1

The General Scope of the Dairy Industry

Dairying, a Universal Industry. Milk is absolutely essential for the growth of the young and for the welfare of the human race. The cow has been rightly called "the foster mother of the human race," and she is found in most of the civilized countries of the earth. Table 1 shows the distribution of cows in some of the principal countries.

The table shows all degrees of intensity of dairying, from one cow for every 1.08 people in New Zealand to one for every 3,188 people in Japan. Some countries produce more dairy products than they can use, and others do not produce enough for their own needs. The United Kingdom is an especially heavy importer of butter, cheese, and condensed milk. Japan would be a heavy importer if the Japanese used dairy products to a greater extent, as they doubtless will in the future.

Some of the factors that determine the present development of the dairy industry in different countries are the relative size of urban and rural population, the adaptation of the country to dairying, the age of the dairy industry in the country, the character of the people, and the extent to which dairy research and education have been developed. In countries where the urban population is large in proportion to the rural population, dairying is developed more along lines of market milk production; these countries are likely to be large importers of manufactured dairy products. In many countries, or

parts of countries, dairying has not been developed because of an excessively hot or cold climate and poor soil conditions.

The dairy cow originated in Europe. Since the population of the United States is made up largely of immigrants from Europe, or their descendants, it is natural that dairying should have reached its highest stage of development in European countries and in America. Many of the European countries that sent their people to settle in America also furnished the foundation cows of our various breeds.

TABLE 1. DISTRIBUTION OF DAIRY COWS IN VARIOUS COUNTRIES[a]

Country	Population[b]	Number of Cows	Number of People per Cow
Australia	9,201,034	2,251,000	4.07
Belgium	8,868,000	990,000	8.9
Canada	65,861,000	3,233,000	20.3
Denmark	4,439,000	1,479,000	3.0
France	43,300,000	9,182,000	4.7
Italy	48,001,000	3,860,000	12.4
Japan	89,269,278	28,000	3,188.1
Netherlands	10,808,576	1,508,000	7.1
New Zealand	2,164,755	1,999,000	1.08
Switzerland	4,978,000	888,000	5.6
United Kingdom	51,221,000	3,777,000	13.5
United States	168,091,000	22,406,000	7.5
West Germany	49,995,000	5,777,000	8.6

Sources: [a] Number of Cows—*Milk Facts*, 1957, Milk Industry Foundation.
[b] Population—*1957 World Almanac* (latest estimates).

Hence one finds all the dairy breeds very well developed in this country. The major dairy breeds are Holstein, Guernsey, Jersey, Ayrshire, and Brown Swiss.

In the United States the dairy industry has grown rapidly, with the number of cows increasing from 8,586,000 in 1860 to 21,232,000 in 1955. These cows had an estimated valuation of $3,225,106,000. As shown in Fig. 1, every state in the Union has its dairy cows, but some states, because of their size and also because they are well adapted to dairying, have many more than others. Between one-third and one-half of the milk cows of the country are owned in 7 states.

The dairy industry in the United States has been developed, for the most part, during the last fifty years. This development has been due largely to record keeping, cooperative bull associations,

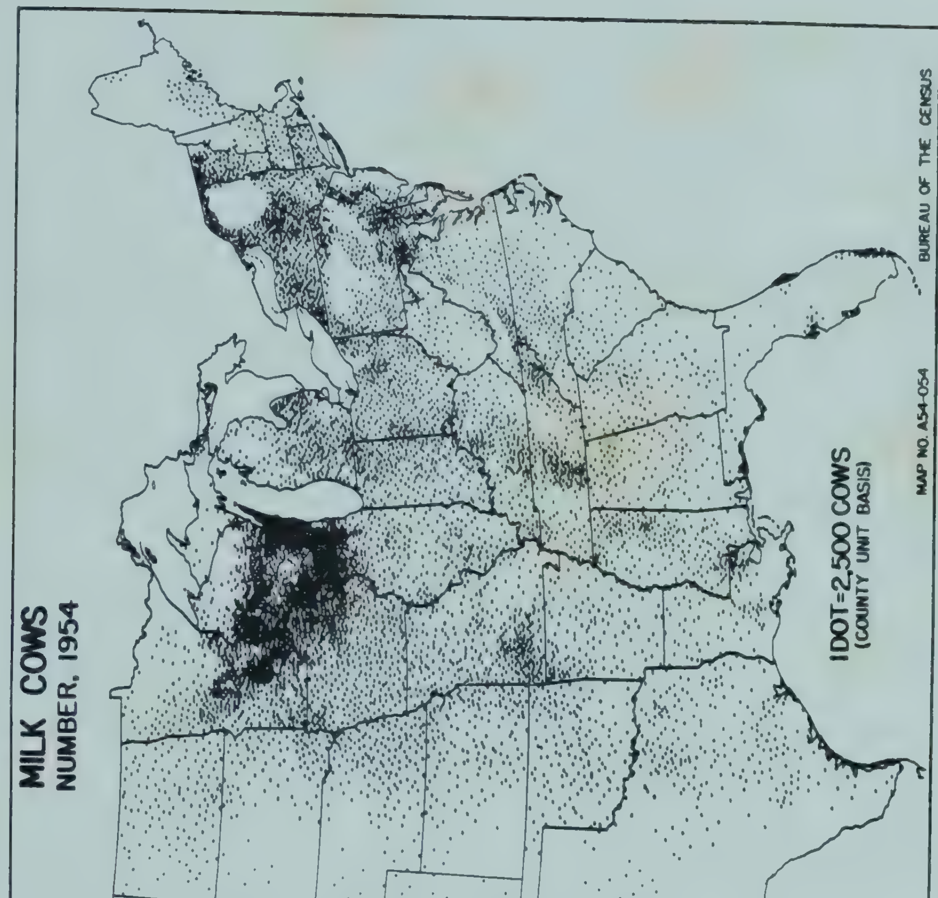

Fig. 1. Distribution of milk cows in the United States. (Courtesy U.S. Department of Commerce.)

artificial insemination, the use of the silo, scientific feeding, the invention of the milking machine, the Babcock test, the centrifugal separator, pasteurization, and cold storage. The large amount of research and educational work done by our agricultural colleges and by the U.S. Department of Agriculture, and our wealth of dairy literature in the form of books and periodicals have contributed much to this rapid development. Research into the value of milk as a food and cooperative advertising by the various dairy organizations are now very effective means of increasing the size of the dairy industry.

The total farm income from major farm products in 1955 was $30,792,462,000. Of this amount, income from milk was $4,212,253,000 and income from sale of animals from milking herds was $1,300,000,000. The total income from dairying of $5,512,253,000 was greater than that from any other single source. Revenue from beef cattle was $5,166,976,000 and the only other single source approaching the value of dairying. The value of the milk alone represented 12.4 per cent of the total farm income of the country. The dairy industry surpasses both the automobile industry and the steel industry in size and scope.

Production and Uses of Milk. In 1955 the cows of the United States produced 123,454,000,000 lb of milk. If this milk were put into square quart bottles placed side by side, the bottles would extend 132 times around the earth. They would provide 700 lb of milk per person in the United States. On a per capita basis, this milk was used as follows: fluid milk, 144 qt; fluid cream, 47 lb; cheese (exclusive of cottage), 8 lb; cottage cheese, 4.5 lb; ice cream, 15.6 qt; butter, 8.8 lb; evaporated and condensed milk, 15.5 lb; dry whole milk, 0.26 lb; nonfat dry milk, 5 lb.

The use of the country's milk products on a percentage basis by products is shown in Fig. 2.

The Main Branches of the Dairy Industry and the Adaptability of Each. One who has traveled very little is likely to assume that the type of dairying practiced in his own locality is typical of the entire dairy industry. A study of Fig. 2 reveals the fact that the dairy industry is divided into a number of different branches, each concerned with the production of a different commodity. These branches may be enumerated as market milk and cream, butter, cheese, condensed and evaporated milk, ice cream, and powdered milk.

The essentials for a thriving market-milk business are a large cen-

How 1956 U. S. Milk Supply Was Used—Includes Milk from Cows Not on Farms

	Million pounds	Per cent of total		Million pounds	Per cent of total
Fluid milk and cream:			Evap. and cond.	6,316	5.0
Cities and villages	49,700	39.5	Frozen dairy prod.*	8,477	6.7
Total farm	10,000	8.0	Fed calves	3,199	2.5
Creamery butter	27,979	22.3	Dry whole milk	820	0.7
Farm butter	2,966	2.4	Miscellaneous factory products and other uses	2,447	1.9
Cheese	13,794	11.0			

* Only that milk used directly in making frozen dairy products. Does not include approx. 1,530,000,000 pounds of milk derived from other manufactured dairy products which when added, give a total of 10,007,000,000 pounds of milk used in the production of frozen dairy products in 1956.

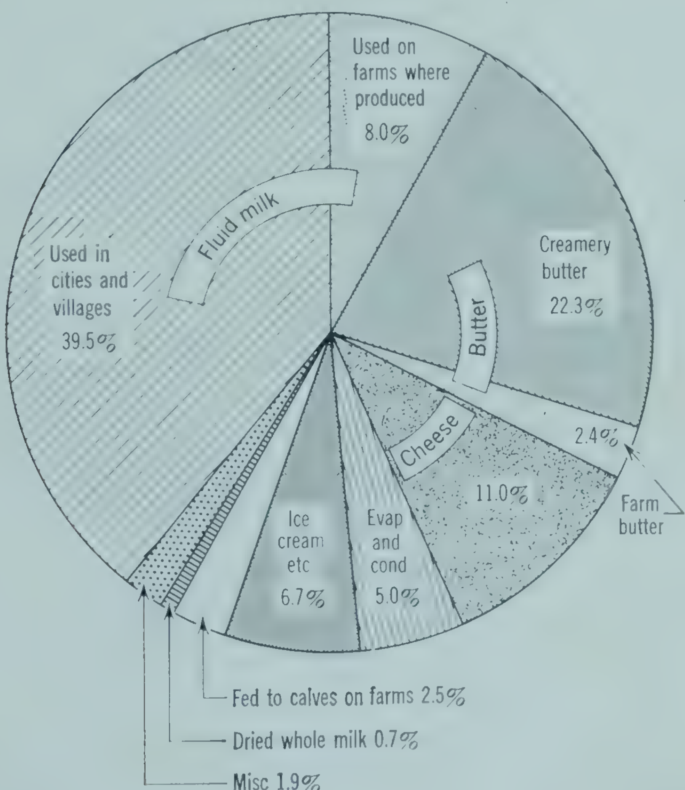

Fig. 2. The uses of milk. (Courtesy Milk Industry Foundation.)

ter of population, good transportation facilities, and good cows. Hence, in the eastern part of the United States, where cities abound, the market-milk business is the principal type of dairy enterprise. The area of the New England States, New York, New Jersey, Pennsylvania, and Delaware is but 3.44 per cent of the area of the United States, and yet 21.28 per cent of the people of the entire country reside in this area. There is no other branch of the dairy industry that brings in so much gross and, in most instances, net profit to farmers as the sale of market milk. When cities become so large that there is a big demand for fluid milk, most of the other branches of the dairy industry must give way.

The butter business thrives where the population is thin, where natural grazing conditions are good, and where grain can be easily grown. The states in the central West possess the necessary prerequisites for buttermaking. There were 1,386,000,000 lb of creamery butter made in the United States in 1955. Almost 50 per cent of this was manufactured in the states of Minnesota, Iowa, and Wisconsin. Some of the butter production is from small herds where dairying is really a side line to grain farming or the raising of beef or hogs.

The cheese business thrives under nearly the same conditions as the butter business, except that in the cheese business it is more necessary to use good dairy cattle, because all of the milk goes to the cheese factory and no skim milk is left on the farm for the feeding of animals. There were 1,002,754,000 lb of cheese produced in this country in 1955, and Wisconsin produced approximately 50 per cent of it. It can be readily seen why Wisconsin is called the cheese center of the world.

The condensed and evaporated milk business thrives under the same general conditions that favor cheese making. The total production for the United States in 1955 was 2,579,831,000 lb of condensed and evaporated milk.

Production of ice cream has grown from 80,000,000 gal in 1909 to 663,210,000 gal in 1958. The ice cream business naturally has been developed along with the market-milk business, for large centers of population are necessary for the success of either.

The milk-powder business is the newest branch of the dairy industry. It is simply the condensed milk business carried one step further and, therefore, it has been developed under much the same conditions. Powdered skim milk is made in much larger quantities than powdered whole milk. The production of powdered skim milk

for 1955 was 1,410,034,000 lb, over one-half of which was produced in the states of Minnesota and Wisconsin. It is now possible in our eastern cities to buy skim milk powder and butter from the West to blend into whole milk, mainly for cooking purposes and for use in ice cream.

Some Advantages of Dairy Farming. Dairy farming offers a number of advantages, among which are the following:

1. Dairy cows produce more edible solids in relation to the amount of food they consume than other farm animals (see Table 2).

TABLE 2. EDIBLE SOLIDS PRODUCED PER 100 POUNDS DIGESTIBLE FOOD CONSUMED[a]

Animal	Edible Solids Produced, pound	Animal	Edible Solids Produced, pound
Cow (milk)	18	Poultry (eggs)	5.1
Pig (dressed)	15.6	Poultry (dressed)	4.2
Cow (cheese)	9.4	Lamb (dressed)	3.2
Calf (dressed)	8.1	Steer (dressed)	2.8
Cow (butter)	5.4	Sheep (dressed)	2.6

[a] W. H. Jordan: *The Feeding of Farm Animals*, The Macmillan Co., 1901.

2. Steady income is provided. A crop of apples or potatoes, for example, brings in money only when the crop is sold, whereas dairying brings in cash to work with every day of the year.

3. Labor is used to good advantage. The grain grower, for example, may have to employ much additional labor at harvest time, but the dairyman has about the same duties to perform every month of the year. Thus less help is required and permanent employees may be kept.

4. The cow turns unsalable roughage into milk. Hay, corn fodder, and other roughage which may not have ready sale are economically used by the dairy cow. Land which is not suitable for cultivation can be used as pasturage for dairy cows.

5. Soil fertility is better maintained. Through the return of manure to the land, the proper fertility and physical condition of the soil are preserved. Usually, when a man gets a run-down farm, the first thing he does is to stock up with cows to increase the fertility

of the soil. After continuous cropping has impoverished the soil, dairying may play an important part in restoring it. The value of plant food sold in an equal tonnage of various farm crops is much less in dairy products than in hay and grain as shown in Table 3.

TABLE 3. FERTILIZING CONSTITUENTS IN FEEDS AND IN ANIMAL PRODUCTS[a]

	Fertilizing Constituents, per cent			Fertility Value, dollars per ton	Manurial Value, dollars per ton
	Nitrogen	Phosphorus	Potassium		
Concentrates					
Corn, dent. No. 2	1.89	0.27	0.29	5.76	3.20
Oats	1.92	0.33	0.43	7.79	4.30
Barley	2.03	0.40	0.49	8.51	4.74
Wheat bran	2.62	1.29	1.23	15.24	9.10
Soybeans	6.06	0.59	1.50	22.68	12.24
Linseed meal	5.63	0.86	1.24	22.32	12.24
Cottonseed meal, 41% protein	6.66	1.11	1.48	26.84	14.79
Tankage, digester, 60% protein	9.50	3.23	0.46	43.85	24.99
Roughages					
Alfalfa hay	2.45	0.24	1.97	10.81	6.10
Clover hay, red	1.92	0.20	1.65	8.66	4.91
Timothy hay	1.06	0.14	1.59	5.73	3.38
Oat straw	0.66	0.09	2.00	4.79	2.96
Corn silage, well matured	0.37	0.07	0.30	1.79	1.03
Animal products					
Fat steer	2.56	0.59	0.14	10.55	
Fat pig	2.32	0.37	0.13	8.81	
Milk	0.56	0.10	0.14	2.31	
Butter	0.14	0.02	0.01	0.52	

[a] Taken by permission of The Morrison Publishing Company, Clinton, Iowa, from the 22nd edition of *Feeds and Feeding*, by F. B. Morrison and Associates.

Major Job Opportunities in the Dairy Industry. Broadly speaking, the industry consists of two main divisions (*a*) the production of milk and (*b*) the handling of milk and the manufacture of milk products. There are worthwhile opportunities in each division and some common to both divisions. These may be set forth in outline form as follows:

A. Milk Production Division
  1. Farm ownership or operating for another.
  2. Feed manufacturing and sales.
  3. Administration of producer cooperative sales organizations and government market orders.
  4. Veterinary medicine.
  5. Work with the various breed associations.
  6. Artificial breeding association work.

It will be seen that for this division of the industry one needs specialized courses in crop raising, feeding, breeding, care, and management of dairy cattle, along with subjects in the arts, sciences, etc.

B. Combined Production and Processing Division
  1. Teaching in schools and colleges.
  2. Extension or field work for educational institutions, the federal government, privately endowed institutions, and commercial organizations.
  3. Research work for educational institutions, state experiment stations, the federal government, and commercial organizations.
  4. Inspectors and sanitary engineers for the federal, state, and city governments.
  5. State dairy control officials.
  6. Manufacture and sale of dairy equipment and supplies.
  7. Work with the National Dairy Council.
  8. Trade association work in the various branches of the industry.
  9. Dairy periodical publishing.

In this area, one needs in addition to dairy courses those in the sciences, arts and letters, and education.

C. The Processing Division
  1. Procurement of dairy raw materials.
  2. Purchasing of supplies and equipment.
  3. Plant supervision.
  4. Research and quality control.
  5. Engineering.
  6. Transportation.
  7. Accounting.
  8. Insurance.
  9. Taxes.
  10. Legal.

11. Industrial relations.
12. Public relations.
13. Sales.
14. Executive management.

In the processing division one needs training in dairy technology, with emphasis on the sciences (for research) and on business administration.

In small companies several of the activities above naturally will be handled by one man. It will be seen that most of the key positions in the dairy industry are held by men. Women, however, are employed in goodly numbers in research and control laboratories and by the National Dairy Council.

Important Features of the Dairy Business as a Place for a Career. The dairy business is big business. Many companies have annual sales

Fig. 3. An exhibit floor of auditorium in Atlantic City, N.J. showing dairy equipment and supplies manufactured by members of Dairy Industries' Supply Association. This biennial exposition is one of the largest in the world

amounting to hundreds of thousands of dollars, and at least one large company, operating over a wide area, has sales of over a billion dollars a year. According to 1954 figures from the U.S. Department of Commerce, 284,000 people were employed in processing; 177,000 of these were in the milk processing and distributing field. More motor vehicles, 380,000 in number, are used for the pickup of milk from farms and for the distribution of milk products to the consumer than for any other commodity.

Both the production and processing divisions provide steady employment. Cows give milk 365 days a year, and since milk is a perishable product, it has to be cared for at once. This is not to say that the industry has kept the 7-day work week in favor of a 5- or 6-day week. What it does mean is that it is the most depression-proof industry imaginable. Even in the depths of the depression of the early 1930's, employment in large dairy companies was kept at 80 per cent normal, or more, when many companies were entirely closed down. It is for this reason that few, if any, industries are likely to equal the earnings from the dairy industry.

It is difficult for a young man who has not been through a depression and who wants to marry and settle down, and who perhaps receives a more tempting offer from another industry, to realize this fact. The potential plant operator's inexperience with a depression accounts, in part, for the current shortage of college-trained men in the industry. He should try to picture for himself a working span of 40 years and to consider the total security he can build rather than the immediate income he can earn.

The dairy industry is so widespread that one can work in it and live almost anywhere he chooses. There is satisfaction to be gained in knowing one is working for the public good since dairy products are so essential and so universally used. The industry also offers an infinite variety of work, all of which makes life very interesting. In all key positions no two days are alike.

It is an industry experiencing constant growth. Indications are that in the years just ahead the dairy industry will expand faster than ever. Babies are being born at a rapid rate, and the number of older people is increasing rapidly. Both of these groups are large users of milk and other dairy products.

Qualifications for a Successful Career in the Dairy Business. Qualifications may be divided into (*a*) basic personal qualities applicable to success in almost any field and (*b*) educational qualifications.

One may have all the educational qualifications in the world and be unsuccessful if he does not possess the basic personal qualities. Some of these will be discussed first. It will be recognized that these qualifications are essential for success in any business.

A. *Basic Personal Qualifications:*

1. Good Health. The universal use of milk and the possibility of its contamination require that personnel have good health; some of the work is heavy and requires strong physique.
2. Honesty. This qualification certainly needs no amplification.
3. Clean Habits. The man who is slovenly in appearance and who cannot refrain from smoking while he works has no place in a dairy plant.
4. Promptness and Regularity. No plant can operate efficiently unless employees report for work on time, and absenteeism, for any avoidable reason, cannot be tolerated.
5. Job Interest. A man must be interested in his job and have some ambition to better his lot.
6. Cooperativeness. To be happy himself and to be a part of a smoothly running organization, a man must get along well with his fellow workers and must be willing to pull his share of the load.
7. The Why and How. A man must know the why as well as the how of his job and its relations to other plant operations.
8. Cost Mindedness. Personnel must understand that both the security of their jobs and their futures depend on company profits, which are affected by their work.
9. Originality. To be successful, an employee must be a thinker who can come up with sound ideas and be able to express them well orally and in writing.
10. Company Policies. The employee should understand all company policies that relate specifically to him.

To develop into a responsible position and to be successful in it, a man must:

1. Be able to do a good job of work planning; otherwise his costs will be too high.
2. Be adept at arithmetic and accounting.

3. Have the knack of, and realize the importance of, teaching the why and how of the job.
4. Be able to handle people in such a way that they will look up to him and give him their respect.
5. Be able to sell himself, his company, and its products.

B. *Educational Qualifications:*

Although little has been said thus far concerning education, there are nonetheless educational qualifications to consider. As soon as possible, the student, with the help of a faculty adviser, should carefully analyze his inclinations and capabilities. He must realize that he needs something besides the vocational training offered in the dairy department's processing rooms and laboratories if he is to properly advance in his chosen field. English composition, public speaking, and mathematics (especially business arithmetic and accounting), are essential for all. Economics and labor relations are likewise important. Business courses should be taken by those inclined toward selling and management and the sciences by those inclined toward research. The mechanically inclined should try to work in some engineering. Those planning to teach or to do research should expect to do graduate work.

Regardless of what his ultimate goal may be in the business field after graduation, a few years of experience should be gained in as many different jobs connected with the business as possible. The man who ultimately fills a key position will do his best if he has been "through the mill." This training also will help the individual to find the place in the business for which he is best suited and in which he will be the happiest. Naturally, positions as managers and presidents of companies offer the greatest financial rewards, but they also carry very heavy responsibilities which one must prepare himself to carry. A college man in the dairy industry often feels that he does not get along fast enough and is getting "lost in the shuffle." The employee must always do his best and the employer should be alert to recognize and reward good work. The employer should take more pains to see that likely prospects get the proper chances to obtain the necessary experience to fit them for key positions. On the other hand, the employee should keep his mind fixed on his goal and learn all he can, not only about the job on which he is working at the moment, but about the job which he knows must be his next steppingstone. Failure to make this preparation, and to sell himself to his superiors in an unobtrusive manner, will result in very slow advancement.

QUESTIONS

1. Why is dairying a universal industry?
2. What are the factors that have determined the development of the dairy industry in the different countries?
3. Why are more than a third of the cows in this country located in seven states?
4. Why are the dairy breeds more widely distributed in the United States than in other countries?
5. What is the size of the dairy industry compared to some others?
6. What are the six main branches of the dairy industry?
7. State the essentials for a thriving market-milk business.
8. Why is most of the butter in the United States made in the Middle West?
9. In what part of the United States is most of the cheese made?
10. Where are the condenseries and milk powder plants located?
11. Where is the ice cream business most popular?
12. State five advantages of dairy farming.
13. What are the major divisions of the dairy industry?
14. Name some of the job opportunities in the milk production division and specialized courses one needs to prepare for these opportunities.
15. Name some of the job opportunities common to both divisions and some of the specialized courses one needs to prepare for these opportunities.
16. Name some of the job opportunities in the processing division and courses needed for preparation for work in this division.
17. What are the features of the dairy business that make it an interesting career?
18. What are some of the qualifications for a successful career in dairying? Which seem the most important to you?
19. How can one keep from getting "lost in the shuffle" when employed in the dairy business?

PROBLEMS

1. What was the percentage increase in number of dairy cows in the United States from 1860 to 1955? *Ans.* 149.60 per cent

2. Assuming the number of cows in the United States in 1957 to be the number that produced the milk in 1955, what was the average production per cow? *Ans.* 5,509.86 lb

3. With an approximate population of 160,000,000 in the United States in 1955, what was the daily per capita consumption of milk for all purposes? *Ans.* 2.11 lb

4. If 22.2 per cent of the milk produced in 1955 was made into creamery butter, how many pounds of milk did it take to make a pound of butter?
Ans. 19.46 lb

5. How many more dollars' worth of fertility was taken from the soil in the form of fluid milk used in cities and villages than in the form of creamery butter (20 lb milk per lb of butter) in 1956? Assume milk produced in 1956 was 124,000,000,000 lb. Refer to Fig. 2 and Table 3.
Ans. $56,112,424.00

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CHAPTER **2**

Essentials of Successful Dairy Farm Operation

The Dairyman. The most important factor in the successful operation of a modern dairy farm is the dairyman himself. A dairyman should be a good businessman. He must know how and when to invest capital and he must be able to determine what his returns are from each item of investment. At the present time a modest size dairy farm operation represents an investment of $40,000 to $60,000, and many large dairy farms involve investments of $100,000 to $200,000. More capital is required per unit of labor on a dairy farm than in almost any other business.

In order to make a farm successful, the operator must combine his own good managerial ability with good location, adequate size of business, high-producing cows, the correct amount of machinery, fertile soil, and a good market. A dairy farm is no place for a second rate man. It can make a good living for a capable man and his family.

Accessibility to a Good Market. A good milk market should be accessible to the dairy farm. If the farm is too close to a center of population, the land price and the tax rate may be excessive. If it is too far away, time required to obtain supplies and services is too great for efficiency. The cost of shipping milk a considerable distance is not nearly as great a handicap as it was before the development of the modern highway and the bulk tank truck. Good roads are very important in present day farming. They save time and money in

transporting farm products to market and in transporting supplies and equipment to the farm. Good roads also decrease the cost of maintaining trucks and automobiles and increase the pleasures of rural life.

Nearness to church and the availability of a good school system also are very important considerations in the selection of a farm.

Although milk may be produced economically, the farm may not be a profitable operation if the product cannot be sold on a satisfactory market. In general, the best milk markets are those which use most of the product in the fluid state. In a 1956 report by the U.S. Department of Agriculture, the average wholesale price of milk destined for fluid purposes was $5.34 per hundredweight, whereas the milk sold to condenseries was $2.92. In order to get the largest return from milk, a dairyman should locate, if possible, in an area where most of the milk goes to a fluid milk market. This location normally would be equipped with rapid and economical transportation to a center of population. The dairyman would attempt to sell to a dealer who sells most of his product in bottles. He might try to join a strong bargaining or distributing cooperative. In any case, he would look for a market which consistently has paid a high price over the years, is in a strong financial position, and has a reputation for selling a high-quality product and for fair dealings with both producer and consumer.

In an area where there is a small demand for fluid milk, most milk must go into butter, cheese, ice cream, and powdered or condensed milk. Under such conditions, dairying must be carried on very efficiently on a rather extensive basis or must be combined with some other farm enterprise. In many cases it is carried on with grain farming or general livestock. In such cases there is a tendency for production per cow to be low and for the operation to be rather inefficient. The success of this type of operation generally comes from the use of low-cost home-grown grain and the year-round use of family labor which would not be used otherwise. Because dairy farm profits depend so heavily on the prices received for milk and livestock, marketing research has increased during the last few years.

State and Federal Milk Control Laws. Although such laws generally have the stated purpose of assuring the public an adequate supply of wholesome milk, they also have an important effect on the financial status of the dairy farmer. In approximately 17 states, prices paid to dairymen are set by a milk control board or other state agency. In some states such boards also regulate prices paid by the consumer.

In addition to these, there were in 1958 a total of 68 markets under regulation of Federal Milk Marketing Orders. These regulations controlled the prices paid for 33 per cent of the total amount of milk sold in the United States, and a very high percentage of that used as fluid milk. It has been stated by reliable authority that if these regulations were modified to permit a free movement of milk, prices paid to one-fourth of the producers of fluid milk in the United States probably would decline an average of 48 cents per hundredweight. In some markets the decline might reach 75 cents to $1.00. The effect of state and federal regulations on milk prices must be considered in selecting an area in which to purchase a dairy farm.

Fertile Soil and Adequate Water. The soil type on which a farm is located is a basic resource which always should be investigated by checking soil maps or by consulting the county agricultural agent or the Soil Conservation Service. A basically good soil can be built up to a high state of fertility, but a basically poor soil is always a liability. A dairy farm always needs large quantities of pure water for home and milk room use. Water for irrigation may be worth many hundreds of dollars in a dry year. When buying a farm it is wise to investigate water use rights and adequacy of supply.

Size of Operation. Dairy farms are becoming fewer but larger in size. The one man operation is rapidly becoming a thing of the past. Although under normal circumstances one man can operate a dairy farm very efficiently without help, he is in a precarious position if he becomes sick or is injured. Besides, the modern dairy farmer wants and is entitled to a day off each week and an annual vacation. This is true for both the hired man and the owner. For this reason the farm and the herd should be large enough to support at least two men profitably. Many economists now say that a dairy farm should have 40 to 50 cows per man and the number recommended is increasing steadily. A 100 cow herd is common in many dairy areas.

The size of the farm in tillable acres will vary considerably among different areas. In grain producing regions the farm normally should be large enough to provide all the pasture, hay, and silage, as well as most of the concentrates needed by the milking herd and the young stock. In other areas, such as New England, the farm usually supplies only the forage needs.

With good management, increasing the size of a dairy farm generally reduces the overhead per cow or per hundredweight of milk

produced. More efficient machinery can be owned profitably and feed and fertilizer can be purchased at more favorable prices. Also, more favorable marketing conditions often can be realized. Size in itself, however, does not guarantee greater efficiency or more profit.

Farm Labor. The modern dairy farm must have skilled and dependable labor to care for high-producing cows and to operate expensive farm equipment. Because this type of labor is not plentiful in most areas, a good farm worker demands and is entitled to a reasonable standard of living for himself and his family.

Many dairymen are able to obtain and to hold over a period of years competent farm labor at a reasonable cost by providing their employees with attractive and comfortable living quarters. Married men frequently are provided with a house, milk, fuel, and meat as part of their wages. Single men often are provided with room, board, and laundry. These perquisites are valued very highly by most farm laborers. Kindness, courtesy, fair treatment, and prompt payment of wages are also necessary in dealing with farm workers. Competent and satisfied workers can contribute much to the success of a farm enterprise.

Efficient Use of Labor. For many years the efficiency of a dairy farm was measured in terms of production per cow. With labor costs taking more and more of the income, emphasis has been shifted to production of milk per acre and per man per year. With the use of modern technology and specialization in dairying, annual production of milk per acre can reach 3,000 lb and production per man 250,000 lb. Some very efficiently operated farms are producing at 1.5 to 2 times these rates.

More efficient use of labor can be achieved by several means. Examples of this are the use of the milking parlor or pipeline milker, the gutter cleaner, and the silo unloader. Little is gained by the use of such equipment, however, unless the labor bill is reduced by more than enough to pay for the cost and operation of the equipment or unless the labor saved is put to a more profitable use. Labor efficiency frequently is achieved by increasing the size of the operation. In a recent study in Minnesota, it was found that to care for a 10-cow herd for one year required an average of 129 man-hours per cow, whereas a 30-cow herd required only about 80 man-hours per cow. This saving resulted partly from the fact that the time required for many chores is not much greater for a large herd than for a small one and partly from the greater use of machinery.

Labor efficiency also can be increased by concentrating on that work which will give the greatest return at any particular time. An outstanding example of poor management is to have a farm crew building a fence or overhauling the hay baler instead of making hay when the feed value of the hay is highest. The efficient manager repairs equipment and paints buildings when more pressing work has been completed. He plans farming operations so as to even out work loads. He is able to use almost the same amount of labor throughout the year and to keep it occupied profitably at all times.

High Producing Cows. Although more attention is being given to high production per man and acre, high production per cow is still important. In general, a moderately high level of production for all cows is much more desirable than a moderately high average with cows varying from one extreme to the other. The fact that a herd is uniformly good usually indicates that it is rather homozygous for high production, and that with good bulls one is fairly sure that production can be maintained from one generation to the next. When production is variable, one does not know what to expect in the next generation. In general the net return from a cow increases with the level of production. This fact is shown very clearly in Table 4, which was adapted from the New Hampshire Dairy Herd Improvement Association report for 1957.

TABLE 4. THE RELATIONSHIP BETWEEN LEVEL OF PRODUCTION AND RETURN OVER FEED COST

Annual Milk Production, pounds	Total Feed Cost, dollars	Value of Milk over Feed Cost, dollars
5,000	150	100
6,000	168	150
7,000	186	200
8,000	204	240
9,000	222	280
10,000	240	320
11,000	257	340
12,000	275	355

Even though the higher producing cows ate more feed than the lower producers, the increased production more than paid for the increased feed. With labor, bedding, stall space, etc., remaining nearly the same for all animals, it is obvious that high production is related to profitable production. It would be interesting to know to

what extent the higher rates of production were due to higher rates of feeding and how much of the high rates of feeding were due to high production. In any case they must go together.

Maximum Use of Home Grown Feed. In addition to low labor costs, efficient production depends on economical feeding. From each dollar of gross income the average New England dairyman in 1956 spent 7 cents for hired labor and 23 cents for purchased feed. For Wisconsin comparable expenditures were 7.3 cents for hired labor and 11 cents for purchased feed. With feed including the cost of home-grown forage being the most important cost in producing milk, maximum use of high-quality, low-cost forage is essential. The average dairyman in the United States feeds a cow 1 lb

TABLE 5. COST OF 100 POUNDS OF TOTAL DIGESTIBLE NUTRIENTS FROM VARIOUS SOURCES

Orchard grass—Ladino clover pasture in rotation with crops	$0.69
Bluegrass—white clover pasture—well managed	0.71
Mixed hay	1.10
Corn silage	1.35
Wheat	2.56
Purchased concentrates @ $80/ton	5.55

of concentrates for each 3.3 lb of milk, or 1,861 lb of concentrates per year to a cow which produces 6,162 lb of milk. In contrast to this, a prominent New Hampshire dairyman fed an average of 580 lb of concentrates per cow in 1957 and had an average production of 11,350 lb of milk and 444 lb butterfat from an average of 29.4 cows during the year. This man has achieved a similar record every year for the last 30 years. All of the nutrients other than the concentrates came from home-grown hay, pasture, and grass silage. Milk is produced at low cost on this farm.

During the past several years, much has been said and written about the advantages of grassland farming. Grassland farming means maximum use of pasture, hay, and grass silage in feeding the dairy herd and minimum use of concentrates. Such a program generally reduces feed costs, maintains an optimum level of production, and conserves the soil. This type of program is particularly advantageous in those areas where climate and topography make the growing of grains more difficult and less economical. The relative cost of nutrients from home grown forages and wheat as compared to purchased concentrates is shown in Table 5. These values are from the U.S. Department of Agriculture and other sources.

When grain can be produced economically on the farm, it generally is desirable to do so if all forage needs have been met first. It is usually better to purchase part or even all the concentrate needs of a dairy herd than to purchase forage. Nutrients from purchased forage usually are high in price, difficult and expensive to transport, and often low in quality. Nutrients from home grown forage usually are cheaper by far than those obtained from any other source.

Minimum Investment in Buildings and Machinery. In order to operate efficiently, a dairyman should have only enough farm buildings to shelter his cattle, feed, and machinery. The large impressive barns of a previous period often are a serious liability. Insurance and taxes on them are high. Maintenance often has to be neglected. A paint job would cost nearly as much as the whole farm would return in profit in a year. In addition to these handicaps, such buildings were designed for a type of dairying which disappeared from the modern dairy farm many years ago. Many dairymen still labor under such a handicap and they have no way to escape from it. In purchasing a farm it frequently would be better to purchase one without buildings and to put the money saved into a minimum-quality building which would provide the necessary shelter and could be used efficiently.

For the reasons mentioned previously and because of the high cost of conventional types of construction, pole-type and all-metal structures have been erected on numerous dairy farms. They are relatively low in cost and can be adapted to changing needs and farming methods. We have just begun to find out how little our livestock require in the way of shelter and equipment. Ostentation is being replaced by improved technology and good business methods.

More and more equipment is finding economical use on the modern dairy farm as a result of the scarcity and high cost of good dairy farm labor. In general, economical use of equipment requires maximum use. Many smaller dairymen own much equipment that they cannot justify on the basis of the labor saved. They simply want to get away from certain hard jobs or else to keep up with their neighbors. In such cases capital invested in this manner is not yielding maximum returns.

Farm equipment is expensive and becomes obsolete quickly. It should be serviced regularly and kept in repair. It should be protected from the weather in order to give trouble-free service and have a high trade-in value. It should be operated carefully in order to prevent breakdowns and injury to the operator. Many successful

dairymen have found that by simplifying their operations and specializing on certain crops, they need less equipment but can get much greater use out of what they do need. This simplification reduces costs and permits the purchase of newer types of equipment as it becomes available. Other dairymen hire custom operators to do jobs such as baling hay and chopping silage. Very recently the practice of renting equipment for short periods of time has come into use. These are other methods for reducing investment and cost.

Specialization. Over the years the dairy farm has become more and more a specialized operation. Cream separation, butter making, processing of market milk, growing and mixing of concentrates, and the keeping of bulls have almost disappeared from the average dairy farm and the trend continues unabated. Replacements now are being raised by dairymen who milk no cows. Many California dairymen buy all of their cows and all of the feed needed and have just enough land for barns and feed lots. The Walker-Gordon Laboratories of Plainsboro, New Jersey, obtains its milk supply from cows owned and cared for by individual contractors. The latest developments in this process are the *cow pool* and *integration*.

The cow pool is an attempt to solve problems involving inadequate dairy farm labor, sanitary regulations, financing bulk tanks and pipeline milkers, and cost of hauling milk. It does this by bringing the milking cows of many dairymen together at a central location. The best known example of this type of operation is the Fashion Farm Cow Pool near Mason City, Iowa. This privately operated enterprise at last report was caring for 800 cows and was still expanding. The owners of the cows pay a fixed fee per cow, plus the cost of feed, care, veterinary service, breeding, etc. The milk is transported by tank truck to Kansas City, Missouri, where it is sold at the grade A price instead of the grade B price previously received by most of the individual dairymen. The owners of the cows are relieved of the care of their cows and can devote the time saved to other endeavors.

In other areas these problems are met by the formation of milking cooperatives. The cows generally are kept at a central location. In some cases each dairyman cares for his own cows but uses a common milking parlor. In other cases the cows are cared for and milked under the supervision of a manager hired by the cooperative. The feed may be produced by the individual dairymen or purchased on the open market. Milking cooperatives must be organized on a very sound basis if they are to function successfully.

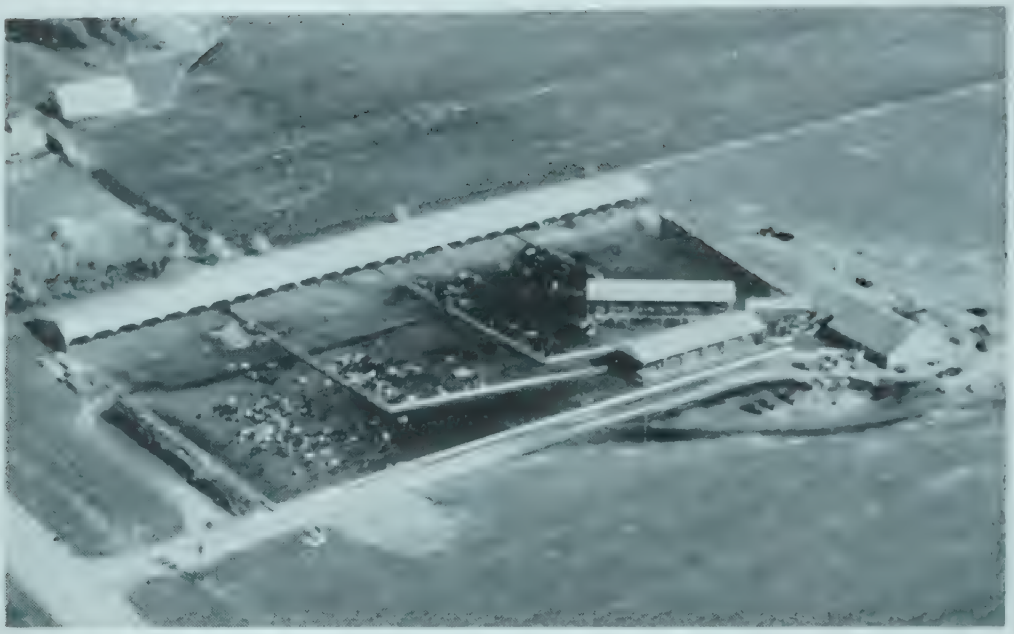

Fig. 4. Fashion Farm Cow Pool, Mason City, Iowa. (Courtesy Mr. B. G. Thrailkill, Des Moines Register and Tribune.)

Integration is a relatively new term in the dairy industry. Horizontal integration refers to increasing the size of an enterprise by such means as the cow pool and the milking cooperative. Vertical integration refers to the type of business organization represented by the common control of a feed manufacturing plant, a cow pool, and a milk processing and distributing plant. Specialization and integration are rapidly assuming an important role in the dairy industry. It is up to the dairy farmer to use them to his own advantage.

Keeping Up-to-Date. Dairy farming is a constantly changing business operation. The successful dairyman must keep up-to-date in those fields of science dealing with soil fertility, plant breeding, crop preservation, animal breeding, animal nutrition, animal diseases, and artificial insemination. Likewise, he must be a businessman having a good working knowledge of cooperative purchasing and selling, credit, accounting, taxes, and insurance.

In order to be competent in so many fields, a dairyman must read the various farm papers and bulletins from his agricultural experiment station and his extension service. He must work with his county agricultural agent and U.S.D.A. service representatives. He

must belong to the sound farm organizations operating in his community and carry his share of the responsibility in working for those programs which are good for the dairy industry and agriculture in general. He should consider belonging to the local artificial breeding association, the Dairy Herd Improvement Association, and the local farm cooperative. He will do well to attend field days and extension meetings held in his county and conferences held at his state university.

These contacts not only help financially but they are of great value in helping a farmer to understand what is taking place in the dairy industry and how to best manage his own business.

QUESTIONS

1. What are the essential qualifications of a successful dairyman?
2. Why is accessibility to market important in selecting a dairy farm?
3. How does the type of market affect the price received for milk?
4. How do state and federal milk control laws affect the dairy farmer?
5. How does the size of business affect the efficiency of dairy farm operation?
6. What factors are important in holding qualified farm labor?
7. List important factors in efficient use of labor.
8. How does value of product over feed cost vary with level of milk production?
9. What is grassland farming and what are its advantages?
10. What are the essential building needs on a dairy farm?
11. What are the advantages and disadvantages of a cow pool?
12. What is vertical integration? Horizontal integration?
13. How can a dairyman keep up-to-date?

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CHAPTER **3**

The Composition and Properties of Milk and Factors Affecting Same

Definition. Milk may be defined as the fluid normally secreted by female mammals for the nourishment of their young. Milk as it is drawn from the cow is known as whole milk.

TABLE 6. AVERAGE COMPOSITION OF THE MILK OF VARIOUS MAMMALS

Mammal	Butterfat	Protein	Lactose	Minerals	Total Solids
			Per Cent		
Cow	4.00	3.50	4.90	0.70	13.10
Goat	4.09	3.71	4.20	0.78	12.86
Woman	3.70	1.63	6.98	0.21	12.57
Mare	1.59	2.69	6.14	0.51	10.96
Ass	1.50	2.10	6.40	0.30	10.30
Sow	6.77	6.22	4.02	0.97	17.98
Ewe	6.18	5.15	4.17	0.93	16.43
Water buffalo	12.4	6.03	3.74	0.89	23.91
Camel	5.4	3.00	3.30	0.70	12.39
Reindeer	18.70	11.10	2.70	1.20	33.70
Whale	22.24	11.95	1.79	1.66	38.14

Average Composition of Milk and Grouping of Milk Constituents. The average composition of the milk of several mammals is given in Table 6. Although various authorities differ slightly in regard to such figures, the values given indicate how milk from the various species differs in composition. Though the various milks contain

the same constituents, the amounts of these solids vary considerably. Through selection and breeding, man has greatly increased the milk producing capacity of those animals whose milk is best suited for human consumption. This is especially true of the cow and the goat. The milk of other mammals, however, including the ewe, mare, camel, and water buffalo, is used as human food. Note particularly the differences in the composition of cow's milk and that of the human mother. Cow's milk fed to infants sometimes has to be modified to match more closely the composition of mother's milk. The term "milk" is usually understood to refer to cow's milk, unless other species are specifically mentioned.

The following figures are a fair average for the composition of milk and are easy to remember:

Constituent	*Per Cent*
Water	87
Butterfat	4
Casein	2.8
Albumin	0.5
Lactose (milk sugar)	5.0
Minerals	0.7

Milk constituents are divided into two groups, namely, the water and the solids. The constituents other than the water are called the total solids (T.S.). The total solids minus the butterfat are termed the solids-not-fat (S.N.F.). All the constituents except the butterfat are known as the milk serum. The casein and albumin make up most of the protein of the milk. Actually about 0.05 per cent globulin also is present.

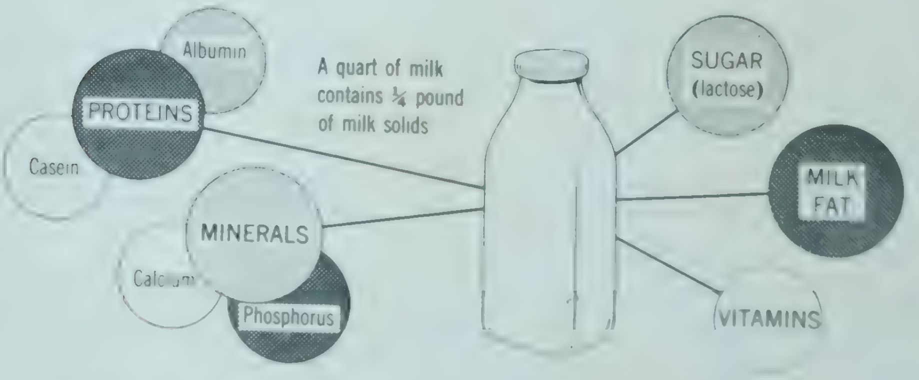

Fig. 5. The various food elements in one quart of milk. (Courtesy of National Dairy Council.)

Variations in the Composition of Milk, Notably the Butterfat Content. The water varies from 82 to 90 per cent; butterfat, 2.5 to 8 per cent; casein, 2.3 to 4 per cent; albumin, 0.4 to 1 per cent; sugar, 3.5 to 6 per cent; and minerals, 0.5 to 0.9 per cent. The main thing to note here is that the water and the butterfat are the most variable constituents. Milk that is high in butterfat is low in water, and vice versa. The mineral content varies less than any other constituent. There are many causes for these variations.

BREED. The figures in Table 7 show the average percentage of butterfat and total solids in the milk of the five major dairy breeds. Note that as the percentage of butterfat increases, the percentage of solids-not-fat in the milk also increases, although at a slower rate. Thus, while the butterfat varies from 3.45 to 5.14 per cent, a difference of 1.69 per cent, the solids-not-fat vary from 8.48 to 9.57 per cent, a difference of 1.09 per cent. The reader should remember, however, that these are average figures; a herd of any one breed often produces milk of considerably different composition from another herd of the same breed.

TABLE 7. AVERAGE BUTTERFAT, SOLIDS-NOT-FAT, AND TOTAL SOLIDS CONTENT OF MILK FROM MAJOR DAIRY BREEDS

Breed	Butterfat	Solids-Not-Fat	Total Solids
		Per Cent	
Ayrshire	3.85	8.87	12.72
Brown Swiss	4.01	9.40	13.41
Guernsey	4.98	9.57	14.55
Holstein	3.45	8.48	11.93
Jersey	5.14	9.43	14.57

THE INDIVIDUAL AND THE HERD. Milk from individual cows within the same breed varies greatly in composition. Some cows of any breed are low testers, some are high testers, and others come near the average. The matter of high or low test is often a family characteristic. Whether the sire or the dam has more to do with transmitting high or low percentage of butterfat in the milk of the offspring, and how much either has to do with it, is an open question. We should emphasize butterfat production instead of butterfat. Butterfat is synthesized in the udder independently of the other constituents. A cow has the ability to produce a certain amount of butterfat and a certain amount of the other constituents of milk. The butterfat test is simply the ratio which exists between the two components.

THE STAGE OF THE LACTATION PERIOD. The lactation period is the period between calvings during which the cow gives milk. The normal period is about 10 months. When the cow freshens, the first milk secreted is called colostrum. Physically, it differs from normal milk in that it is thick and yellow. Chemically, it contains somewhat more casein, albumin, globulin, chlorine, and minerals than normal milk and somewhat less lactose. The average composition of colostrum, determined by Engling and reported by Richmond, is as follows: water, 71.69 per cent; butterfat, 3.37 per cent; casein, 4.83 per cent; globulin and albumin, 15.85 per cent; sugar, 2.48 per cent, and minerals, 1.78 per cent. It has been shown that what was formerly considered a high albumin content is in fact largely globulin. This globulin content may run as high as 13 per cent in the early colostral period. Colostrum also contains several times the normal amount of various vitamins, has a laxative effect, and is especially valuable for the newborn calf. Colostrum changes to normal milk in from 2 to 10 days, and the milk is generally considered fit for human consumption after the sixth milking following freshening. If a cow calves in medium flesh, or in what might be called a normal condition, her milk tests 0.5 to 1.5 per cent lower during the first few months of her lactation period than during the last 2 months. The largest increase takes place during the last 3 months, since butterfat production does not decline as rapidly as the production of the other constituents. The effect of advancing lactation on the percentage of butterfat is closely associated with the effect of the season of the year and the condition of the cow at calving.

THE CONDITION OF THE COW AT CALVING TIME. If a cow is excessively fat, her milk tests abnormally high for a period of 2 weeks to 2 months after calving. It pays to have cows freshen in good condition, as their milk tests higher after calving and they produce more heavily over a longer period of time.

SEASON OF THE YEAR. Milk tests higher in fall and winter than in spring and summer. No one knows exactly why this is so. The effect of rising temperature and high humidity on the cow's system seems to be the main cause. Experiments have shown that it is not due to green pasture feed, as is commonly supposed. The figures in Table 8 show the percentage of butterfat and solids-not-fat, for a period of 10 months, in the milk of 9 cows which calved in January.

It will be noted that the milk tested about 0.3 per cent butterfat lower in June and July than in the winter, and that the percentage of S.N.F. fell off nearly twice as much. It is unfortunate that milk producers, in sections where milk is sold on a test basis, do not more

generally understand that this variation occurs. There is usually a general complaint, in April or thereabouts, because the tests are lower than they were in the preceding month. The man doing the testing gets a lot of blame for something he cannot help.

TABLE 8. VARIATION IN FAT AND SOLIDS-NOT-FAT CAUSED BY SEASON OF YEAR

Month	Fat, per cent	S.N.F., per cent
January	3.95	8.70
February	3.93	8.77
March	3.70	8.50
April	3.68	8.50
May	3.76	8.62
June	3.61	8.23
July	3.62	8.10
August	3.77	8.20
September	3.83	8.53
October	4.02	8.72

Storrs Bull. 94.

FIRST DRAWN AND LAST DRAWN MILK. The first milk drawn from a cow at a given milking tests much lower than the strippings, or last milk. This is shown in the following figures, which were obtained in a class exercise. The reason for this condition is explained in the chapter on milk secretion.

Stage of milking	*Butterfat Content, per cent*
First streams	1.6
25 per cent drawn	3.25
75 per cent drawn	5.0
Strippings	8.3

This record is from one cow only. The strippings from a Jersey cow frequently test as high as 10 to 12 per cent. These figures clearly show the necessity of milking the cow dry before getting an accurate test of her milk at a certain milking. Failure to milk the cow dry also results in a decided loss of butterfat and tends to dry the cow off prematurely.

MILK FROM DIFFERENT QUARTERS OF THE UDDER. Milk from different quarters tests differently. It is clear that if one expects to get an accurate test on a cow's milk at a certain milking, each quarter must be milked dry. The variation is probably due to the fact that

the four quarters of the udder are independent glands and function differently.

TIME BETWEEN MILKINGS, AND EXERCISE. If cows are milked at regular intervals, the milk usually tests the highest after the shortest interval. The influence on the butterfat is known to be much greater than on the solids-not-fat. The more regular the milking period, the less will be the variation.

In experiments in which the interval between milkings has been kept equal, the morning milk is slightly lower in butterfat than the evening milk. This difference is evidently due to the effect of the exercise the cow gets during the day. It has been shown that exercising cows by walking them usually increases slightly the test of the milk.

THE AGE OF THE COW. A cow is considered to be in her prime from the third to the sixth lactation period, inclusive. All available data indicate that the percentage of butterfat changes but little during the first six lactation periods. After this time there is a gradual decline; and if a cow continues to produce milk at 14 to 16 years of age, it may test 0.5 to 1 per cent lower than the milk she produced when she was in her prime. The greatest reductions, of course, occur with cows which gave high-testing milk when in their prime.

CHANGE OF MILKERS. A cow soon gets used to a certain milker, and if a change is made the milk is likely to vary in percentage of butterfat. It may go either up or down until the cow becomes accustomed to the change.

FEED. Most farmers attribute any change in the test of their milk to feed. Much experimental work, in addition to that mentioned in the previous paragraph, has been done on the subject. Although the results differ somewhat, in the main they agree in showing that even though sudden or radical changes in feed may affect the percentage of butterfat in milk, it is not possible for feed changes to bring about any material or permanent increase in the butterfat content. After changes in feed, the percentage of butterfat soon tends to return to the normal for the cow or herd affected.

HEAT PERIOD. The test of a cow's milk when in heat means but little and is generally not a true indication of what her milk may test 24 hours afterward. The percentage of butterfat may go up or down, depending on the cow.

EXCITEMENT. A cow ordinarily is housed under quiet conditions. Even under these conditions her milk will vary in test from milking to milking and from day to day. Environmental conditions likely to

cause excitement, such as those prevailing at a cattle show or fair, may lead to wide variations in the milk test.

SUDDEN AND SEVERE WEATHER CHANGES. Severe weather changes disturb the cow's system and affect both the amount of milk she gives and the test of the milk. The test may vary either way.

SICKNESS. When a cow is sick, her milk may be very abnormal. It may test either higher or lower than her average milk. No reliance can be placed on a test taken at this time.

INFLUENCE OF DRUGS. It has been thought that the extremely high tests sometimes were due to the use of various drugs in the feeding of the cows. Experimental work on this matter shows that drugs cannot be relied upon to produce uniformly high tests. In fact, the use of drugs may cause a reduction in the test, and in the milk flow as well.

FREQUENCY OF MILKING. Under ordinary conditions, cows usually do not give enough extra milk and butterfat, when milked three or four times a day to pay for the extra labor. In advanced registry work, where the cow must make her best possible record, it used to be common practice to milk three or four times a day. This practice largely has been discontinued, however. There is no indication that this practice affects the percentage of butterfat in the milk over a given period. The average percentage of butterfat for a number of cows on advanced registry tests was 3.93; the same cows kept in the same herds under ordinary conditions gave milk testing 4.08 per cent. Hence, it can be seen that frequency of milking has no appreciable effect on the butterfat test of milk.

COMBINATION OF CAUSES. A combination of the factors mentioned above may cause the percentage of butterfat to vary. It seems almost unbelievable that a cow's milk may test 3.5 per cent butterfat at 6 A.M. and 5 per cent when drawn only a few hours later.

FACTORS AFFECTING THE MINERAL CONTENT. Various factors affect the mineral content of milk, as well as the proportion of the various salts present. It is well known that the variation in the mineral content from one milk to another is sometimes marked. Udder infections, such as mastitis, increase the mineral and chlorine content of milk. The mineral content, which is high in colostrum milk, decreases to a level that is constant for most of the lactation period, and increases again towards the end of lactation. Experiments are conflicting as to the effect of feeds on the mineral content. Evidently variations in feed have little if any effect on the minerals of milk. Bacterial growth in milk tends to lower the citrate content of milk. The ratio between the various salts in milk minerals is affected

by the season of the year; the percentage of calcium and magnesium is highest in the late winter.

The main idea in the preceding paragraphs is that water and butterfat are the most variable constituents. Milk that is high in butterfat is low in water and vice versa. The mineral content varies less than any other constituent.

Properties of Milk. TASTE AND ODOR. Milk produced under proper conditions has a slightly sweet taste and a mild aromatic flavor and aroma. The sweet taste comes from the lactose and the flavor and aroma principally from the butterfat. Both the flavor and the odor are readily affected by unclean surroundings or by the feeding of the cow.

COLOR. Normal milk has a yellowish-white color due to the presence of butterfat and casein and small amounts of coloring matter. The butterfat and casein exist in a finely divided state of suspension, and hence prevent light from showing through the milk. This opacity causes the milk to appear white. The breed of the cow and the feed have an effect on the color of milk. Guernseys and Jerseys give the yellowest milk, Ayrshires and Holsteins the whitest. Milk is a deeper yellow when the cows are on pasture than when they are on dry feed. This color is due to carotene which the cow absorbs from the green feed.

SPECIFIC GRAVITY. The term specific gravity, as applied to milk, means the weight of a given volume of milk compared with the weight of the same volume of water at the same degree of temperature. The specific gravity of water is 1; that is, 1 ml of water at 4° C weighs 1 g. The average specific gravity of milk is 1.032, which means that 1 ml of milk at 4° C weighs 1.032 g. In other words, milk is 1.032 times as heavy as water. According to Richmond, butterfat has a specific gravity of 0.93, and the solids-not-fat, 1.616. The solids-not-fat, being present in larger proportion than the fat, make milk heavier than water. A quart of water weighs 2.08 lb and a quart of milk 2.15 lb.

BOILING POINT. The boiling point of milk ranges from 212° to 214° F.

FREEZING POINT. The freezing point of milk is about 31° F, varying very slightly with the percentage of solids in the milk.

ADHESION OF MILK. A piece of paper wet with milk will stick to glass or wood like a gummed label. This property of milk is due mainly to the casein.

VISCOSITY. Milk is a little thicker, or more viscous, than water, because of the solids of the milk.

OTHER CHARACTERISTICS OF MILK. When milk is heated to a temperature near the boiling point, a tough film, which is mostly casein and albumin, forms at the surface. Lower temperatures, such as the pasteurization temperature of 142° F, cause no change in the properties of milk. Prolonged boiling of milk causes it to darken in color to a light brown, and the flavor is changed.

When milk sours from the growth of acid-forming bacteria or from having acid added to it, the milk thickens and forms a soft, jelly-like, white clot. The solid material is known as curd and the clear liquid which separates from the curd is called whey.

When fresh milk is tested with litmus, it turns blue litmus pink and pink litmus blue. This property of appearing both acid and alkaline is called "amphoteric." Milk, however, is considered to be slightly acidic in reaction. When titrated with a standard alkali, it appears to contain 0.12 to 0.2 per cent acidity, calculated as lactic acid.

The Water of Milk and Its Use. The water in milk is the same as any other water. Its function is to hold the solids of the milk partly in solution and partly in suspension.

Butterfat—Its Properties and Uses. Butterfat exists in milk as an emulsion. When a droplet of milk is examined under a powerful microscope, myriads of small spherical, butterfat globules are visible. The size of the globules varies from the milk of one cow to another, and there are also breed differences. Sometimes the butterfat globules are single, but frequently they stick together in little clumps. The butterfat globule is surrounded by a thin membrane, the composition of which is the subject of considerable study. This membrane is important in keeping the butterfat from becoming a free oil and causing so-called "oiling off" when milk is heated, as in pasteurization, or agitated as in handling in cans or tanks. The membrane also may serve as some protection against the action of enzymes, notably lipase, in causing butterfat to become rancid. The size of the globules and the amount of clumping depend on many factors and are of commercial importance. The size and arrangement of the globules affect the creaming ability of milk, the viscosity of cream, the ease of whipping cream, and the churning of cream into butter. There may be as many as 100,000,000 butterfat globules in a single drop of milk. The size of these globules varies with the breed of the cow and the stage of the lactation period. Milk from the high-testing breeds contains the largest globules. When a cow is going dry before calving, the butterfat globules become very

small. Butterfat is composed of glycerol and a rather varying mixture of several fatty acids. About 12.5 per cent of these are soluble in water, and the rest are insoluble. It is the soluble portion of the butterfat that is mainly responsible for the absorption of odors by milk, whereas the proportion of insoluble compounds affects the hardness of the butterfat and hence the hardness of butter. Butterfat is the lightest constituent of milk. It is because of this fact that the cream, which contains most of the butterfat in the milk, rises to the top to form the cream layer. The butterfat is in a liquid condition when milk is drawn from the cow but solidifies at about 92° F. Because of change in dietary habits, butterfat does not rate the importance it once held. Butterfat is a very rich source of energy and also a good source of vitamins A and D. Milk is bought and sold almost entirely on a butterfat differential basis. For example, if 100 lb of milk testing 4.3 per cent butterfat is taken to the dairy, the farmer might be paid $5.00 per cwt for 3.7 per cent milk, plus 7 cents additional for each 0.1 per cent over the basic test or actually $5.42. Butterfat is one of the principal constituents of almost all dairy products, such as butter, cheese, and ice cream.

Casein—Its Properties and Uses. Casein belongs to the class of substances known as proteins. Casein is found in no other product than milk. It exists in milk in combination with calcium, hence is often spoken of as calcium caseinate. It is present in milk in a finely divided suspension similar to clay in muddy water or flour in water. Such a suspension is known as a "colloidal" dispersion. Casein is precipitated, or separated out of milk, when the milk sours or when acid or rennet is added to it. The casein is then known as curd and becomes the main constituent of cheese. Rennet is a constituent of the gastric juice of the stomach. It is obtained commercially from the stomach of the milk-fed calf at slaughter. Because casein is a protein, it supplies the body with muscle-building material.

Casein, which is used in many articles of commerce, is separated from milk by precipitation, by means of dilute acid or rennet. The curd is separated from the whey, pressed, and dried in hot chambers. The dried casein is a hard, granular, yellowish-white material. One of the principal uses of casein is in the manufacture of glue. It makes a glue which, when dried, is strong and moisture-resistant. This glue is used in furniture, wood products of all kinds, automobile bodies, refrigerators, and so on. Another use of casein is as a main constituent of cold-water-soluble paints. Casein is used successfully for sizing writing paper, wall paper, and the like, and as a

Fig. 6. Casein fiber.

sizing material for cloth. Plastics, which are used as substitutes for celluloid, horn, and tortoise shell are made from casein. Many of the materials one uses daily are made from casein plastic, such as buttons, combs, fountain-pen barrels, electrical insulation materials, and like products. Casein is used in food materials (as in baby foods), as a binder in sausages, and in meat sauces. One of the most interesting recent developments is a casein cloth which is very much like wool in its properties. This casein fiber, called "Lanital," is used as a substitute for wool to a considerable extent in some countries as in Italy, where it was first developed commercially.

Albumin and Globulin—Properties and Uses. The proteins, albumin, and globulin are present in small amounts, dispersed in the water of the milk. The approximately 0.5 per cent albumin present is similar to the albumin in the "white of egg" or blood albumin but is not identical with either. Albumin can be separated out of milk whey as a fine white curd by heat. Albumin and globulin serve the body in the same way as casein. Albumin is of some use commercially.

Because it is not precipitated by acid, albumin is one of the principal constituents of whey. Powdered whey is used as a poultry feed and in calf milk replacers. Primost cheese, made by boiling off the water from whey, contains a large proportion of albumin.

Usually the first milk secreted after calving (colostrum) contains sixteen times more albumin and globulin than normal milk. This amount decreases rapidly to normal during the first few milkings.

Lactose—Its Properties and Uses. Lactose is the only carbohydrate normally in milk. Lactose has the same formula as cane sugar, but it differs from cane sugar in sweetness and other properties. Cane sugar (sucrose) is about six times as sweet as lactose. Lactose serves the body as a source of energy, but is not as rich as butterfat in this respect. It takes 2.25 lb of lactose to equal the heat value of a pound of butterfat. Lactose is easily changed by bacterial action to lactic acid, a change which causes milk to taste sour. The breaking down of lactose by bacteria to lactic acid is not desired in milk, cream, or ice cream. In some dairy products, such as soft cheese, commercial buttermilk, and butter, the characteristic flavor is partly due to this acid fermentation.

Lactose is an important constituent in milk products. About 40 per cent of the total solids of milk itself is lactose. More than half of the solids in skim milk and dried skim milk are lactose, and many other dairy products contain a goodly amount of lactose. Since this sugar is not very soluble, it sometimes separates or "crystallizes" in such dairy products as sweetened condensed milk and ice cream, producing a "sandy" condition. It is necessary to control or prevent the crystallization of the lactose in these products.

Lactose is obtained commercially from whey by a process which includes evaporation of whey. The principal uses of lactose are in making coatings for pills and fillers in medicines and in modifying milk for infant feeding. A sweet form of lactose, known as beta-lactose, can be made. Beta-lactose is nearly as sweet as cane sugar and nearly as soluble. It is now known that lactose has nutritive properties not possessed by other sugars. People who are advised to use lactose for their health's sake find beta-lactose a satisfactory substitute for cane sugar.

Minerals—Properties and Uses. The mineral content of milk is the least variable of all milk constituents. Milk minerals are composed of acid and alkali salts of potassium, calcium, sodium, and so on, partly in solution and partly in suspension. Because of the fact that

the metallic elements are in excess of the nonmetallic, the mineral content is always alkaline in character. Milk minerals are very essential as a food for the young, as they help to build bone and promote the proper development of the teeth. The principal mineral constituents in one quart of cow's milk are as follows: Calcium, 1.170 grams (g); magnesium, 0.117 g; potassium, 1.394 g; sodium, 0.497 g; phosphorus, 0.907 g; chlorine, 1.034 g; sulphur, 0.332 g; iron, 0.002 g; iodine, a trace. Even though the average mineral content of milk is only 0.7 per cent, the presence of this constituent furnishes one of the principal reasons why milk is such an important food, especially for children.

Testing of atomic and hydrogen bombs has resulted in much commentary on radioactive fallout. This has centered around the absorption of strontium-90 in foods, notably milk. Much testing has been done and is continuing to determine any possible effect of strontium-90 on the health of human beings, particularly on human bone structure. Effects on bone structure are being studied because chemically strontium-90 and calcium are similarly related.

Strontium-90 from fallout is deposited upon forage crops and the upper surface of the soil. Hence it may find its way into milk by way of the food which the cow eats. No one is likely to escape harmful effects from fallout simply by eliminating milk and milk products from the diet, since all other foods contain strontium-90. The fact is that the ratio of calcium to strontium-90 in milk may be protective, according to Dr. G. P. Whitlock of the National Dairy Council, who says, "At present levels, the strontium-90 in two glasses of milk consumed daily for 200 years will produce less radioactivity than that of a single chest x-ray." The evidence at the present time indicates that some of the statements that have been made concerning the significance of strontium-90 in milk are exaggerated.

At the meeting of the American Dairy Science Association held in June 1959, Dr. Demott and Dr. Easterly of the University of Tennessee reported that an Atomic Energy Commission Research team has shown in its experiments that up to 94 per cent of radioactive strontium-90 can be removed from milk by an ion exchange resin. The process is not yet ready for commercial use, but the writers believe that should the need arise, commercial use could soon be developed.

Minor Constituents of Milk. The water, butterfat, proteins, lactose, and minerals are termed the major constituents of milk because they

are present in comparatively large quantities and make up the bulk of the product. There are a number of other substances in milk, which are often called the minor constituents. Some of these substances, though present in very small amounts, are very significant. The more important ones will be discussed briefly.

VITAMINS. Milk is one of the principal sources of the important food substances known as vitamins. All the known vitamins are present in milk, though not all in abundance. The kind and quality of feed given the cow are known to influence the vitamin content of milk. Vitamins will be more fully discussed in Chapter 22.

PIGMENTS. Milk contains two fat-soluble pigments, "carotene" and "xanthophyll," and one water-soluble pigment, "lactoflavin" (lactochrome). Carotene is mainly responsible for the yellow color of butterfat. When the cow eats carotene-rich feeds, some of the pigment gets into the blood stream and finally into the milk. The amount of color passed into the milk varies with the breed as well as the feed. Green grass, green silage and forage crops, carrots, and green alfalfa hay are the principal feeds rich in carotene. The amount of the water-soluble pigment (lactoflavin) in milk varies with the breed and the individual cow.

CHOLESTEROL. The amount of cholesterol in milk varies directly with the butterfat content of the milk. Cholesterol is a yellow-white fatty chemical compound found in such foods as eggs, meat, and dairy products. Because the body needs cholesterol to build cells and to manufacture important hormones, it also makes it own cholesterol, notably in the liver. When a substance containing cholesterol is subjected to ultraviolet rays, the cholesterol changes to vitamin D. This is the basis of one method of making "vitamin-D" milk.

PHOSPHOLIPID. The principal phospholipid found in milk is called "lecithin." Lecithin is a fat-like substance containing nitrogen and phosphorus. The lecithin is closely associated with milk fat, and when milk is separated, some of the lecithin remains in the butter, though most of it passes into the buttermilk. When the lecithin in butter is broken down chemically, it forms trimethyl amine, and the flavor defect known as "fishy" butter is produced. This same defect occasionally develops in other dairy products, such as evaporated and dry milk.

ENZYMES. Several enzymes are known to be present in milk, and the presence of some enzymes is of considerable importance. An enzyme is an organic compound, produced by a living cell, which affects the speed of a chemical reaction without becoming a part of

the substances formed. An example of an enzyme is that of the enzyme in rennet extract (rennase), which greatly increases the coagulation of milk. A number of enzymes are present in the digestive juices of the body, such as pepsin, found in the stomach.

Lipase is an enzyme in milk which hastens the breakdown of milk fat, thus causing a strong or "rancid" flavor. *Galactase* slowly reduces milk proteins to simpler compounds; hence it plays a part in the "ripening" of some cheeses. *Lactase,* as its name implies, hydrolyzes lactose into the simpler sugars, *glucose* and *galactose.* Two forms of *diastase,* a starch-splitting enzyme, have been shown to be present in milk. The enzyme *oleinase* is said to play a part at times in the development of "oxidized" or "cappy" flavor in milk. *Peroxidase* and *catalase* are enzymes normally found in milk, but neither affects its flavor or keeping quality in any way. Some *reductase* is found in milk, largely as a result of bacterial growth. The amount of reductase, as measured by the methylene-blue reductase test, is frequently used as a rough measure of the bacterial content of milk. *Phosphatase* is a normal constituent of milk, which has the ability to liberate free phenol from alcoholic esters of phosphoric acid. This activity of phosphatase is measured in the phosphatase test for the pasteurization of milk. The activity of the enzyme should be almost entirely destroyed by pasteurization. Other enzymes than those briefly discussed herein have been reported as present, but it is doubtful if they are normally present in all milk. The enzymes of milk are destroyed or almost entirely inactivated by the pasteurization of milk. Some enzymes are inactivated at temperatures considerably below the pasteurization temperature. For example, prevention of a strong or rancid flavor in cream requires that lipase not be permitted to act in warm milk prior to separation. It is a common commercial practice to heat milk to 115° or 120° F to inactivate the lipase, and then cool it back to about 90° F for separation.

GASES. Milk contains some absorbed gases, as carbon dioxide, oxygen, and nitrogen. Carbon dioxide enters the milk in the cow's udder, and oxygen, nitrogen, and other gases get into the milk during milking. Gases also may be formed by the growth of certain bacteria. The gases in milk have no special importance, slowly pass from the milk as it stands, and almost entirely escape during pasteurization.

NITROGENOUS SUBSTANCES. Other nitrogen-containing compounds besides the proteins already mentioned are found in milk in small quantities. Other proteins are said to be present in small quantities, such as fibrin, mucoid protein, and an alcohol-soluble protein.

Other nitrogen-containing substances which are not proteins but are found in milk in very small amounts are uric acid, creatine, urea nitrogen, and traces of amino acids.

QUESTIONS

1. What different milks are suitable for human consumption and how do they differ principally in composition from mother's milk?
2. What is the average composition of milk?
3. Which constituents of milk vary the most; which the least?
4. What is milk serum; S.N.F.; T.S.?
5. Rank the breeds from lowest to highest according to percentage of butterfat in their milk.
6. Where would you expect the greatest variation in test, in milk of individuals or in herd milk? Why?
7. What is the effect of advancing lactation on the percentage of butterfat in milk?
8. What effect does the condition of the cow at calving time have on test of milk?
9. How does the season affect the composition of milk?
10. What happens to the test of a cow's milk when she is not milked dry?
11. Would milk from three quarters represent the test of a cow's milk at a certain milking?
12. What is the effect on the test of late morning and early afternoon milking?
13. How does a change of milkers affect the test of a cow's milk?
14. How does feed affect the percentage of butterfat in milk?
15. Why cannot a test be relied upon when a cow is sick or in heat?
16. How does excitement affect the test of milk?
17. Write down ten assumed tests on ten consecutive milkings of a single cow, kept under normal conditions, thus showing your idea of how they might vary.
18. What is the influence of drugs on the percentage of butterfat in milk?
19. How does the frequency of milking affect the butterfat test?
20. What factors cause the solids-not-fat content of milk to vary?
21. What are some of the causes of variations in minerals? Which of the minerals are subject to change?
22. What components of milk make it yellowish-white?
23. What is the average specific gravity of milk, and the average weight of a quart of milk?
24. Why does milk boil at a slightly higher temperature and freeze at a slightly lower temperature than water?
25. What is the reaction of milk, and what are some causes of differences in the reaction of milk?

26. What are the principal food elements present in milk?
27. Discuss the physical and chemical properties of butterfat.
28. What are the physiological and commercial uses of butterfat?
29. Describe the properties and principal commercial uses of casein.
30. What is milk albumin and its uses?
31. Describe the properties of lactose.
32. How is lactose obtained commercially? What are its uses?
33. What are the principal minerals? Why are the minerals of considerable importance?
34. Name the enzymes which are present in milk and discuss their importance.
35. Name and discuss other significant "minor constituents" of milk.

PROBLEMS

1. (*a*) Change 632 qt of milk to lb. (*b*) Change 1,205 lb of milk to qt.
Ans. (*a*) 1,358.80 lb
(*b*) 560.46 qt

2. Refer to table of comparison of metric and customary weights and measures in Appendix I and calculate the weight of a quart of skim milk having a specific gravity of 1.036. *Ans.* 2.16 lb

3. A cow produced in one year 30,451.4 lb of milk. Supposing this to be of average composition, how many pounds of casein did she produce? Albumin? Lactose? Minerals? Butterfat? How many gallons of water? *Ans.* 852.64 lb casein; 152.26 lb albumin; 1,522.57 lb lactose; 213.15 lb minerals; 1,218.05 lb butterfat; 3,191.89 gal water.

4. If a cow produced 17,563.7 lb of milk that contained 3.25 per cent butterfat and 11.75 per cent T.S., how much butterfat did she produce? How many lb of T.S.? How many lb of milk serum?
Ans. 570.82 lb butterfat; 2,063.73 lb T.S.; 16,992.88 lb milk serum

5. Three cows together produced 23,456.1 lb of milk in a year. "A" produced 321.6 lb of butterfat "B" and "C" together produced 16,484.1 lb of milk. If the three cows' milk averaged to test 4 per cent, how much did the milk of "B" and "C" average? *Ans.* 3.74 per cent

6. Using the figures in Table 7, how many more lb of butterfat would a Jersey cow produce in giving 6,000 lb of milk than a Holstein in giving 7,000 lb of milk? *Ans.* 66.9 lb

7. A cow produces 15,000 lb of milk and 600 lb of butterfat per year. Forty per cent of this milk is produced in the first 4 months, and the test of this milk is 3.5 per cent. How much more butterfat would the cow have produced if the first 4 months' milk had tested the same as the last 8 months' milk? *Ans.* 49.2 lb more butterfat

8. A cow gives 20 lb of 4 per cent milk at a certain milking. The first 2 lb tested 2 per cent and the last 2 lb 7 per cent. What would the milk have tested (*a*) if the fore milk and the strippings had been rejected? (*b*) if only the strippings had been rejected?

Ans. (*a*) 3.87; (*b*) 3.66

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CHAPTER **4**

The Secretion of Milk

The Mammary Gland. The highly developed mammary gland of the dairy cow is the basis of the dairy industry. More rudimentary forms of this gland are found in other species. The lowest form is represented by the Australian duckbill. This species has 100 to 200 lobules on each side of the median line of the abdominal wall. Each opens to the outside through a duct which is like a sweat pore. The milk oozes out to form a drop on a hair from which the young licks it. There is no nipple.

In the kangaroo and the opossum 10 to 20 ducts come together in a single teat, but each has an individual opening in the end of the teat. There is no milk cistern. The teats are located in a pouch or marsupian into which the young are placed. In higher forms, such as the sow, ducts empty into a common cistern with one teat draining it. The cow represents the highest form of development with all mammary glands being located together in one unit.

The Cow's Udder. EXTERNAL APPEARANCE. The four mammary glands of the dairy cow are grouped together in a structure called the udder. The udder should be reasonably large, possess a level floor, and be neatly attached both front and rear. The teats should be squarely placed, hang perpendicularly, and be of good size. Defective udders may be pendulous or pear-shaped, cut up between the quarters or halves, or may lack one or more quarters. The teats may be short or hard to milk.

GENERAL STRUCTURE. The udder is composed of two principal types of tissue, secreting and connective. A limited amount of con-

nective tissue is necessary for support of the glands. When it is present in excessive amounts, a leathery condition is produced. The desirable udder is one which contains a minimum amount of connective and fatty tissue and a maximum amount of secretory tissue. It shrinks away to nothing after milking and upon massage feels soft and pliable without the presence of lumps or knots. Fibrous growths may be caused by bruises or mastitis. Sometimes entire quarters become diseased and fail to secrete milk.

INTERNAL STRUCTURE. The udder is divided into right and left halves by a heavy membrane which extends lengthwise of the body

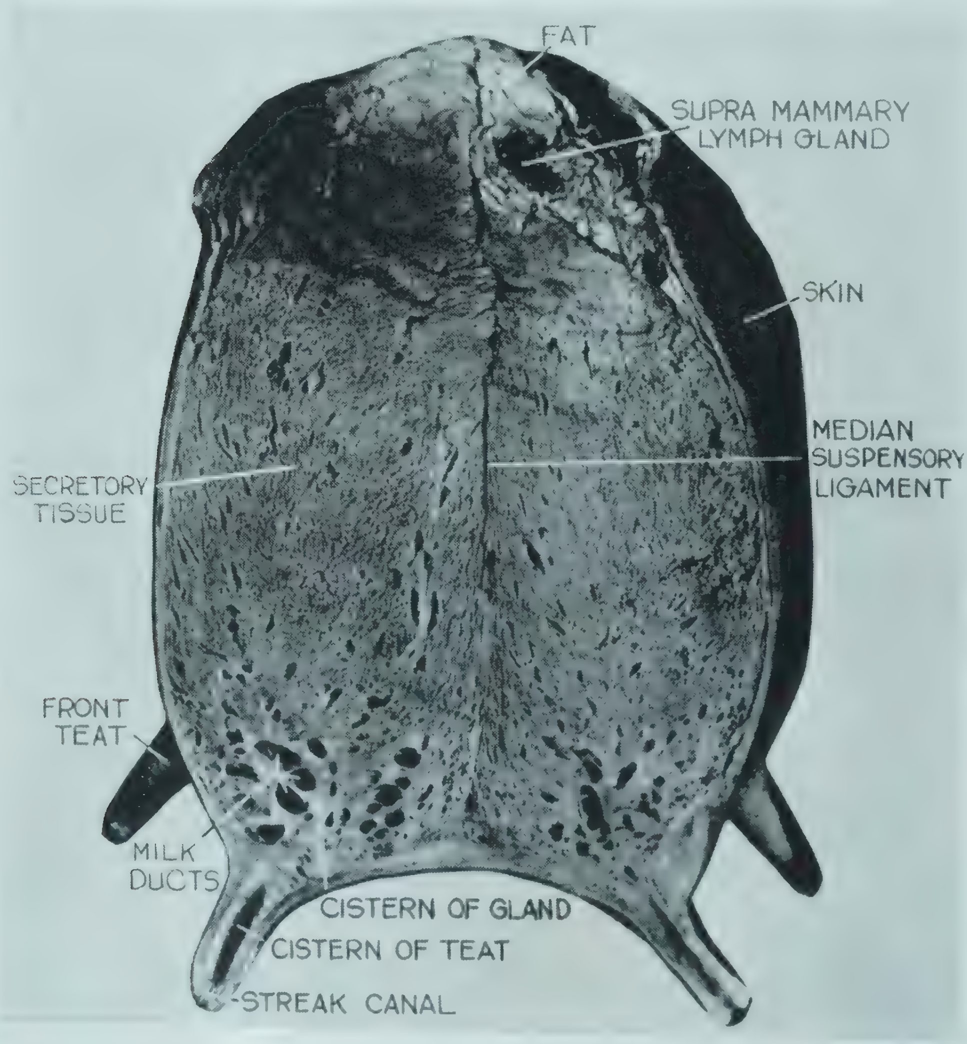

Fig. 7. Cross section of the rear quarters of a cow's udder. (From Missouri Agricultural Experiment Station Bull. 344.)

and helps to support the udder by its attachment to the abdominal wall. Front and rear quarters are separated by a very thin connective tissue membrane. The milk from each quarter can be removed only from the teat of that quarter. At the end of the teat is the opening through which the milk is removed. This opening is called the streak canal and is surrounded by a sphincter or circular muscle. This muscle normally keeps the stored milk from running out. If this muscle is not tight enough, teats may leak milk at milking time; if too tight, the milk is hard to remove.

The teat widens out into the cistern of the teat, which opens into the larger cistern of the gland. Occasionally a membrane closes the teat cistern, resulting in a blind quarter because milk cannot be removed. Leading into the cistern of the gland are 8 to 12 large milk ducts which branch into all parts of the gland and carry the milk secreted down to the cistern. Each gland is divided into lobes, separated by connective tissue membranes which appear as white glistening bands between the orange-colored glandular tissues. The lobes are further divided into lobules, each made up of a large number of hollow spherical structures called alveoli. The cells lining the alveoli, called epithelial cells, first manufacture the milk from the constituents of the blood, then discharge the milk into a hollow cavity called the lumen.

All individual cells in an alveolus are similar in structure. Each contains a nucleus, a structure essential to a living cell, and watery material called protoplasm. In some way, not yet entirely understood, the cells of the alveolus take various raw materials from the blood which flows through the extensive capillary system surrounding the base of the epithelial cells, and convert them into the various constituents of milk. It is estimated that 300 to 400 volumes of blood pass through the udder for each one volume of milk secreted.

Although individual cows show great differences, on the average each of the front quarters produces about 20 per cent of the milk and each of the rear quarters, about 30 per cent. There is almost no difference in production between the right and left halves of the udder.

CIRCULATORY SYSTEM. The arterial blood from the heart reaches the base of each half of the udder through an external pudic artery which comes through the inguinal canal. Each of these branches into two mammary arteries, the cranial, which supplies the forequarter, and the caudal the rear. These arteries branch to supply blood to the mammary glands. Blood from the capillaries collects in two large veins, one at the base of each half of the udder, which

are joined together by a smaller vein in the rear. There are three routes by which blood can return to the heart. One is the so-called "milk vein" or subcutaneous abdominal vein. The second is the external pudic vein which parallels the external pudic artery. The third route is the perineal vien which carries the blood through the pelvic arch. Although the milk veins often are used as an index of milk producing ability, they can be tied off without effecting milk production.

LYMPHATIC SYSTEM. Although most of the fluids which bathe the epithelial cells are returned through the venus system, part are returned through the lymphatic system. The lymph vessels of the udder carry lymph upward and toward the rear of each half where it passes through the supramammary lymph glands. These remove bacteria and foreign matter. When the udder is congested at calving time, it is simply the accumulation of large quantities of lymph.

NERVOUS SYSTEM. The growth of the udder and secretion of milk are not under the control of the nervous system. Milk let-down, the release of certain hormones, and the regulation of blood supply to the udder, are under nervous control. Spinal nerves carry the nerve impulses which cause the pituitary gland to release the let-down hormone into the blood stream. The sympathetic nerves probably influence the volume of blood flowing through the udder.

Udder Development. The udder starts to develop very early in the growth of the fetus. At birth it consists of the teats, the cisterns of the teats, the cisterns of the glands, secondary sprouts, which later form ducts leading into the cisterns of the glands, and some fatty material. As the calf grows the udder increases in size, but there is little growth of ducts. When the heifer reaches puberty, the hormone estrogen, which is produced by the follicles on the ovaries, stimulates development of the duct system at each heat period. During the first pregnancy growth of the duct system becomes continuous rather than cyclic. With the production of the hormone progesterone by the corpus luteum, fine ducts develop from the larger ones and finally the alveoli develop. During the growth period when milk is not secreted the alveoli remain collapsed. This stage of development takes place during the first half to two-thirds of pregnancy.

During the last part of pregnancy the alveoli begin to enlarge with the secretion of colostrum, the first milk produced after calving. This colostrum, discharged into the lumen of the alveolus and the ducts, causes the udder to increase in size. Although the increase in size ordinarily is thought to be due to udder growth, actually it is due to

the secretory activity of cells formed previously. After the colostrum has been removed following parturition, milk secretion becomes intense. It ordinarily increases for approximately one month and then declines until the animal is dried off.

How Milk Is Made. Milk appears to be made by a combination of filtration of certain constituents from the blood stream, cell degeneration, and the synthesis of other constituents by means of true cell metabolism. The last method is by far the most important.

Butterfat appears to be synthesized in the gland, apparently from neutral blood fat. The fact that the short chain fatty acids found in the butterfat are not found in the blood indicates that blood fat is altered by the mammary gland by the removal of two carbon units. The synthesis of butterfat appears to take place independently of that of other milk constituents. This conclusion is supported by the fact that each butterfat globule is surrounded by a membrane composed of phospholipid, a material not found elsewhere in milk.

Milk proteins appear to result partly from synthesis and partly from filtration. Casein and albumin are not present in the blood and must, therefore, be synthesized from blood precursors. Globulin of milk appears to be identical to blood globulin and apparently diffuses from blood. Some work indicates that casein and albumin may be synthesized from blood globulin.

Lactose or milk sugar is not found in the blood. It appears to be synthesized from glycogen in the secreting cells of the gland. It would appear that any material in the blood which can be converted to glycogen can be used in the synthesis of lactose.

Vitamins, certain mineral salts, urea, and various flavoring compounds from the feed apparently pass from the blood to the milk without change. They do not seem to be essential ingredients in the synthesis of milk. Certain body cells are found in the milk, but these appear to result from the normal wear and tear incidental to milk secretion and are not a necessary component of milk.

How Milk Is Discharged. At the beginning of the cycle of secretion, the secreting cells are low and cuboidal in form. The gradual synthesis of milk causes them to lengthen, and particles of butterfat (fat globules) begin to collect in the end of the cells facing the lumen or cavity of the alveolus. As the cells fill with secretion, they are emptied into the lumen. It has been suggested that, after the removal of milk at milking time, the cycles of milk secretion and discharge are rapid, filling the lumina of the alveoli, the ducts and storage spaces of the duct system, and the gland cistern. During

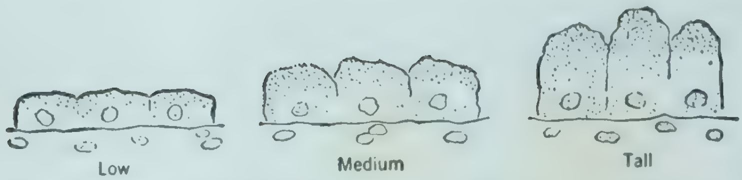

Fig. 8. The cycle of secretory activity within the epithelial cells. (From Missouri Agricultural Experiment Station Bull. 344.)

this period there is little change in the size of the udder or milk pressure, and the secretion of milk proceeds at a rapid rate. With the continued secretion and discharge of milk there is a gradual rise in udder pressure. The cycles of secretion and discharge begin to slow down. This slowing down is due to the unfavorable effect of the increasing milk pressure on the blood capillaries, which reduces the flow of blood, and to the greater and greater difficulty encountered in discharging the cell's content of milk into the lumen. The increasing milk pressure is believed to cause a gradual change in the mode of milk discharge from the cell. With low pressure the cells rupture the membrane and discharge their contents. With higher and higher milk pressure, the cell wall no longer is able to rupture, and the milk is discharged from the cell only as it is possible for it to pass through the semipermeable cell membrane. The butterfat which is in suspension in the milk serum cannot leave the cell and, as a consequence, accumulates within the cell. As secretion continues, a milk which is low in butterfat and, to a less extent, casein, but is normal in sugar and albumin is discharged. Thus the milk secreted when the milk pressure is low is high in butterfat, but as the interval between milkings lengthens, this milk is gradually diluted by the discharge of a milk less rich in butterfat. Therefore, as the interval between milkings lengthens, the butterfat content of the total yield of milk is reduced. This theory explains the reason for the increase of the butterfat content of milk during the milking process and for the richness in butterfat of the strippings, for upon the release of milk pressure, the cells rich in butterfat discharge the accumulation of fat globules. It also explains why the butterfat percentage of milk increases with decreasing production (advanced lactation or temporary inhibition).

Milk Let-Down. As soon as one begins the milking process, either by hand or by machine, a small quantity of milk can be removed from the cistern and the larger ducts. The stimulus of milking causes the posterior lobe of the pituitary to discharge a hormone called

oxytocin into the blood stream. In about one minute it reaches the udder and causes a contraction of the smooth muscles in the udder forcing the milk from the lumina of the alveoli down the duct system into the cistern. Soon there is a great inflow of milk into the cistern, and the milker says the cow has "let down" her milk. While the contractions continue, milk can be removed very rapidly from the udder. After about 8 minutes the gradual disappearance of the hormone permits the muscles to relax and, if milking has not been completed, the last milk cannot be removed. For this reason a rapid milker obtains more milk than a slow milker. Sometimes cows get into the habit of "letting down" their milk only upon being fed, whereas others respond to the noise of milking, feeding, or the presence of their calves.

When cows are disturbed by barking dogs, shouting, or ill-treatment, they frequently will not "let down" their milk. This situation is believed to be due to the discharge of adrenalin from the adrenal glands when animals are excited. Adrenalin causes a relaxation of the smooth muscles of the udder and prevents the normal action of oxytocin upon the muscles. Later, when the adrenalin has been eliminated from the blood, the cow again can "let down" her milk upon the stimulus of milking. A scientific basis thus has been discovered for the importance of treating cows gently and maintaining an environment of contentment.

The Milking Process. For two reasons "harvesting the milk crop" is the most important single process in the entire dairy farm operation. In the first place this is the ultimate purpose for which dairy cows are kept. In the second place it is a very critical process from the standpoint of getting maximum yield and maintaining a healthy udder. Poor milking procedures can easily result in an appreciable loss in production, as well as the loss of function in one or more quarters due to mastitis infection.

In order to remove milk from the udder properly and completely, one must understand the principles involved in the milking process. With hand milking the teat cistern is pinched off at the base of the teat and then the milk in the teat is squeezed out as shown in Fig. 9. Machine milking, as illustrated in Fig. 10, is an entirely different process. With most milking machines vacuum is applied continuously to the end of the teat, but in an alternating manner on the outside of the teat cup liner. This pulsating application of vacuum averages about 48 to 60 times per minute. Contrary to what many people believe, milk is not squeezed from the teat by the collapsed condition

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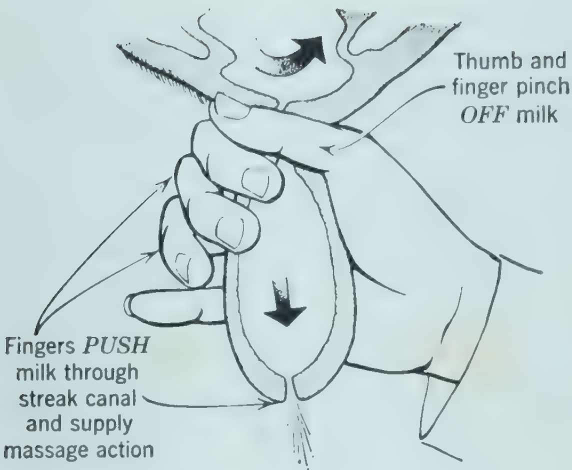

Fig. 9. An illustration of the principle involved in hand milking. (Courtesy Babson Bros. Co.)

of the teat cup liner as shown in Fig. 10*B*. This action massages the teat and helps to prevent congestion in the teat walls. Milk is removed from the teat when vacuum is applied to the outside of the teat cup liner, as shown in Fig. 10*A*. The vacuum level generally varies from 10 to 16 in. of mercury, depending on the design of the particular make of machine.

There are two general types of milking machines. The *floor type* has the teat cups connected to a claw, which is connected to a pail

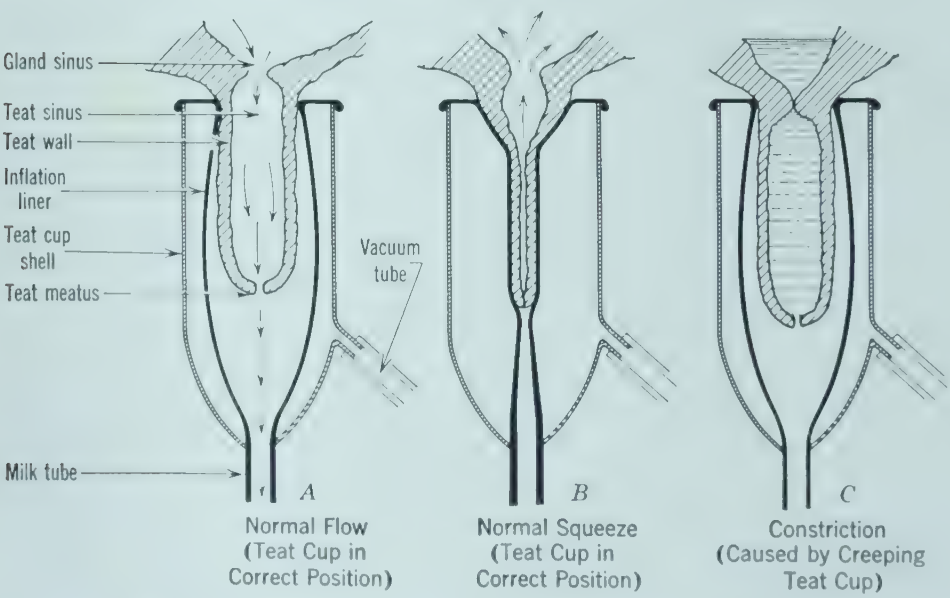

Fig. 10. Machine milking. (Courtesy Babson Bros. Co.)

that sits on the floor about three feet away. The *suspended type* of machine has the teat cups connected directly to the lid of the pail, which is suspended under the cow immediately in front of the udder. The advantages and disadvantages of both types will not be discussed here. The successful use of any type of milking machine depends principally on using it according to the manufacturer's instructions and in keeping it in a good state of repair.

During the past several years the terms "managed milking," "fast milking," etc. have entered the dairy vocabulary. These terms resulted from the efforts made by milking machine companies, veterinarians, and extension workers to teach dairymen good milking procedures. As a result there has been a saving in time devoted to the milking process, a reduction in losses due to mastitis, and a more complete harvest of milk. A good milking procedure may be outlined as follows:

1. Prepare each cow by washing and massaging her udder with a clean cloth or paper towel wet with warm water (approximately 120° F) containing a suitable sanitizer. Check the milk from each quarter with a strip cup. Leave quarters or cows producing abnormal milk until all normal animals have been milked. Discard any abnormal milk.

2. One minute after use of strip cup, attach and properly adjust the milking machine.

3. When milking is nearly completed, "machine strip" by massaging the udder with one hand and pulling down on the claw with the other. In the case of the suspended machine, change the suspension of the pail so as to exert a greater pull on the teat cups and massage the udder with both hands. When a particular quarter is completely milked, that teat cup should be removed from the teat and the entire machine should be removed just as soon as the milking process has been completed. Continued operation of the machine after the milk has been removed may result in the teat cups creeping up on the udder, as shown in Fig. 10C, and causing injury in the lower part of the udder. If one prefers, he may hand strip instead of machine strip but machine stripping is generally preferred. The milking process should be completed in about four minutes.

5. After the teat cups are removed from a cow they should be dipped in clean water to remove the milk, then into a solution of a suitable sanitizer. Some dairymen use an extra set of teat cups so that a sanitized set is ready to be placed on the next cow.

6. After the milking machine has been removed, the teats should

be dipped into a bottle or pan containing a suitable sanitizer. The drop of milk remaining on the teat is removed. This practice tends to reduce the attraction for flies and decreases the chance of bacteria being picked up and carried through the streak canal into the udder.

7. It is very essential that a dairymen develop a good milking routine. Every part of the operation should fit into a pattern which will permit the operator to work at a reasonable pace, allow the proper time after stimulation before the machine is attached, assure complete milking, prevent the machine from remaining on the cow too long, and prevent waste of time of operator or machine.

8. The milking machine should be washed and cared for as outlined in Chapter 15.

For further details it is suggested that the literature put out by the various milking machine manufacturers be consulted.

Hormone Control of Milk Secretion. A pituitary hormone called *lactogen* initiates and is necessary for the maintenance of lactation. There is evidence that the rate of milk secretion may be dependent in part upon the rate of production of this hormone, for its injection into some lactating cows causes an increase in milk production. Studies of the amount of this hormone in the pituitary of cattle and experimental animals indicate (*a*) that the beef cattle pituitary contains smaller amounts than that of dairy cattle; (*b*) that the hormone increases after parturition; (*c*) that there is a decrease in the amount present with the advance of the lactation period; (*d*) that the stimulation of milking causes a discharge of the hormone from the pituitary into the blood stream.

Other hormones of the pituitary have been shown to influence established lactation. Several of these influence the rate of secretion of other endocrine glands, such as the adrenal and thyroid; others influence the amount of the various constituents of blood from which milk is synthesized or manufactured.

Thyroxine, the hormone produced by the thyroid gland, has been shown to have the ability to increase the rate of milk secretion of many cows into which it is injected. *Thyroprotein*, a synthetic thyroxin, has been tested rather extensively during the last several years as a practical and economical means of increasing milk production. Various workers are not in agreement on the results, however.

Drying Off Process. Following the peak of production there is a gradual reduction in the size of the udder and the amount of milk

secreted. Following the cessation of milking there is a rapid shrinking of the glands due to the disappearance of the alveoli. This process is called *involution.* The alveoli are replaced before the start of the next lactation due to the effects of the hormones, estrogen and progesterone.

When the udder is not milked out completely, the drying off process is hastened. Alveoli are not emptied, and pressure is built up rapidly, thus reducing the rate of secretion. The pressure may reach the level at which secretion is stopped and some of the constituents in the milk are returned to the blood stream. This occurrence upsets the secretory process and hastens involution.

Inheritance of Milk Production. Little doubt remains at the present time that the endocrine system, coordinated by the pituitary gland, controls the processes regulating the growth of the mammary gland and the secretion of milk. Cows inherit the ability to secrete varying amounts of milk. Endocrine studies indicate that these differences are due, in major part, to the rate of secretion of the hormones influencing the growth in size of the udder and those influencing the secretion of milk. One cow's inheritance of pituitary secretion may result in the development of a small udder, another's a large udder. Some cows may be deficient in the secretion of the lactogenic hormone and for that reason may be poor producers. Similarly, the thyroid gland may play an important role in maintaining lactation at a high level.

Eventually it may be possible to determine the strength and weakness of families and individuals in regard to the rate of secretion of the various hormones which play a role in milk secretion. This knowledge would give a picture of the cow's inheritance for milk production comparable, in a sense, to the analysis of a soil for its content of various plant foods. By the selection of animals which secrete the hormones in the most nearly proper proportions for maximum milk secretion, and mating animals which supplement each other's deficiencies, genetic and endocrine science might make possible more rapid improvement in dairy cattle.

QUESTIONS

1. What is the essential difference between the mammary gland of the dairy cow and that of the other species of mammals?
2. List the desirable external features of a cow's udder.

3. List the desirable features of the structure of the cow's udder.
4. What are the main parts of the udder?
5. What is the function of the alveoli?
6. Do the various quarters of the udder yield the same amount of milk?
7. What systems are concerned with the manufacture of milk in the cow's udder?
8. Outline the steps involved in udder development.
9. How is it thought that the various constituents of milk are formed in the cow's udder?
10. What is the relation of pressure in the udder to milk flow from same?
11. What is thought to be the reason for a higher butterfat content in the strippings than of the first milk drawn?
12. Why is a rapid milker likely to get more milk from a cow than a slow milker?
13. What are some of the factors involved in the "letting down" of milk by the cow?
14. Why is the milking procedure very important?
15. How is milk removed from the udder by hand milking?
16. How does the milking machine remove milk from the udder?
17. Outline a good milking procedure.
18. What do hormones have to do with milk secretion?
19. What is "involution" and when does it occur?
20. Why do some cows inherit the ability to produce more milk than others?

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CHAPTER 5

The Dairy Breeds

Dairy Cattle. This term is used to distinguish those cattle which are bred primarily to produce milk from those which are used primarily for meat production. In between these two groups are dual purpose cattle which are kept for the purpose of producing both milk and meat. A breed of dairy cattle may be defined as a particular group of animals developed in a certain area for a definite purpose and having the same general characteristics such as color, conformation, and quality of product. A purebred dairy cow is one all of whose ancestry traces back to the same breed. A grade dairy animal is one which has most of the physical characteristics of a particular breed but all of whose ancestry does not trace to the same origin. A registered dairy cow is a purebred which has been registered by the particular breed association. There are five major breeds of dairy cattle in the United States. Listed in order of number of registered animals, they are Holstein, Guernsey, Jersey, Ayrshire, and Brown Swiss.

The average level of milk and butterfat production and average butterfat test for each of the dairy breeds is indicated by the Herd Improvement Registry averages given in Table 9.

The United States milk and butterfat production record holders for each breed are given in Table 10.

The H.I.R. averages give a good indication of how much milk and butterfat large numbers of cows actually produce. The United States milk and butterfat records show what is possible under the best of conditions. Such records stimulate good dairymen to do an even better job in breeding and caring for their cows. In comparing

TABLE 9. HERD IMPROVEMENT REGISTRY AVERAGES FOR EACH BREED
(305-day, mature equivalent, twice-a-day milking)

Breed	Year	Milk Production, pounds	Butterfat Test, per cent	Butterfat Production, pounds
Ayrshire	1957	10,479	4.12	432
Brown Swiss	1957	11,138	4.05	450
Guernsey	1957	8,839	4.86	430
Holstein	1957	13,187	3.69	486
Jersey	1958–59	8,475	5.29	448

TABLE 10. UNITED STATES PRODUCTION RECORDS FOR EACH BREED[a]

Breed	Name of Cow	Year	Milk Production, pounds	Butterfat Test, per cent	Butterfat Production, pounds
	Milk production				
Ayrshire	Greycrest Freda 366234	1957	23,793	4.2	1003
Brown Swiss	Lee's Hill Keeper's Raven 171673	1958	34,850	4.53	1579
Guernsey	Haddon's M. Ida 1245489	1958	28,787	4.3	1235
Holstein	Green Meadow Lily Pabst 2802406 (GP)	1951	42,805	2.9	1246
Jersey	Marlu Milady 1726368 (E)	1958	25,293	4.8	1210
	Butterfat production				
Ayrshire	Neshaminy Miss Phett 269618 (E)	1952	20,946	4.9	1036
Brown Swiss	Letha Irene Pride 170154	1959	34,810	4.98	1733
Guernsey	Langmeadow Minnie 1104226	1957	26,695	5.5	1461
Holstein	Princess Breezewood R A Patsy 3816059	1960	36,821	5.07	1866
Jersey	June Volunteer Fantasy 1546757	1952	20,097	6.6	1319

[a] Ayrshire records are calculated only on 305-day, twice-a-day milking basis; Langmeadow Minnie and Princess Bseezewood R A Patsy were milked twice-a-day, 365 days, all others were milked three times a day, 365 days.

the production levels of the various breeds, one should keep in mind the relative size of the animals of each breed. A small cow producing a moderate quantity of milk often is more efficient and produces more per unit body weight than a large cow producing a much greater quantity. The lactation records of cows producing milk containing different percentages of butterfat can be compared when

converted to an energy equivalent basis by Gaines' formula which is as follows: $0.4 \times$ lb milk for lactation $+ 15 \times$ lb butterfat for lactation $=$ 4 per cent fat corrected milk (F.C.M.) for lactation.

The Ayrshire Breed. This breed was developed in county Ayr in southwestern Scotland. The breed name comes from the name of the county. The Scotsman, a natural-born cattleman, did an unusual job of moulding a breed which could do well under the rugged conditions of the hill country of the area. Summer pastures were often poor and winter rations consisted principally of straw and root crops. By knowing what he wanted and selecting for it, the Scotsman developed a uniform breed which still carries those characteristics which he developed. The first important importation into the United States was made in 1822. Numerous animals have been imported from Scotland and from Canada since that time. Animals of this breed are found throughout the United States, but larger numbers are found in the northeastern part of the country.

This breed of cattle is characterized by its red and white color, shapely udders, general symmetry, balance, and smoothness of body. The red color varies from cherry red to mahogany red, which is different from the reds found in other breeds. The proportion of the two colors varies greatly. The horns of Ayrshires are long, spreading,

Fig. 11. Alfalfa Farm Ann 2nd. Undefeated grand champion that demonstrates the desired Ayrshire type. (Courtesy Ayrshire Breeders' Assoc.)

and curved up at the ends. They are one of the distinguishing characteristics of the breed. Some polled animals are found. Animals of this breed are quite nervous and sometimes hard to manage. They are unexcelled grazers and maintain good body condition even when kept under poor feeding conditions. The meat of the breed is characterized by white fat. Cull animals bring a favorable price when sold for slaughter. Mature Ayrshire cows weigh about 1,200 lb.

Ayrshire milk contains about 4.1 per cent butterfat and is whiter in color than that of the Island breeds. It makes an ideal market milk. The animals of this breed make an excellent appearance in the show ring because of their snap and style and very desirable conformation. No group of breeders is more loyal to a particular breed than the breeds of Ayrshire cattle.

The registry organization for this breed, the Ayrshire Breeders' Association, Brandon, Vermont, has been characterized over the years as being very progressive. It was the first breed association to use electronic equipment to process production records and to compute sire provings. It was the leader in deemphasizing the production testing of selected cows (Advanced Registry) and vigorously promoted production testing of all purebred cows in the herd (Herd Improvement Registry). It also can claim many other firsts in breed improvement programs.

The Brown Swiss Breed. The Brown Swiss breed was developed in the rugged hills and valleys of Switzerland and particularly in the canton Schwyg in the eastern part of the country. The breed has been developed over a period of many centuries. In Switzerland the breed was kept for three purposes, milk, meat, and draft. The animals of this breed produced a good amount of milk and were rugged enough to be able to make the change from winter housing in the valleys to the lush pasture of the mountains in the summer. Both oxen and cows served as work animals. Specialization for dairy purposes took place in the United States after 1900. The first importation into the United States was made in Massachusetts in 1869. The largest numbers are found in the North Central States and in New York and Pennsylvania.

Brown Swiss cows weigh about 1,400 lb. The calves average around 100 lb at birth. Brown Swiss cattle are quite different from other dairy breeds in color and conformation. Color varies from a silver to a dark brown. The nose and tongue are black and a light colored band extends around the nose. Spotting is seldom found and

Fig. 12. Lee's Hill Keeper's Raven. An outstanding Brown Swiss cow. (Courtesy The Brown Swiss Cattle Breeders' Assoc.)

is very undesirable. Calves are light in color at birth, but become darker with age. Horns incline forward and slightly upward. They are moderately small at the base, medium in length, and taper toward black tips. Brown Swiss are rugged, heavily muscled, and lack some of the refinement of other dairy breeds. Heifers are slow in maturing and usually do not come into production until about 3 months later than Holstein heifers. The gestation period also is about 7 to 10 days longer than for other dairy breeds.

The Brown Swiss is an excellent grazer and does well on ordinary pastures. This has been a factor in the development of the breed in this country. Animals of this breed are docile and not easily excited. They produce a 4 per cent milk which is suited for both fluid and manufacturing purposes. The cows are said to be persistent producers and also have long productive lives in the herd. Because of the heavy muscling, large size, and light colored fat, they rate particularly high in beef value when they are sold for slaughter.

The breed registry organization is The Brown Swiss Cattle Breeders' Association, Beloit, Wisconsin. The Brown Swiss cow is popular among "dirt farmers." The association is a progressive organization and has done a commendable job in promoting the breed. This organization was the first dairy breed association in the United States to open its herd books to grade animals which met certain high

standards of breeding and production, but this policy was later rescinded.

The Guernsey Breed. This breed originated on the Channel Islands which are near the north coast of France. The islands have a temperate climate and a productive soil. Because of the small size of the islands and the strong demand for land for growing vegetables and flowers for export, the breed of cattle being developed had to be very efficient to maintain a place in the economy.

It is thought that the cattle which were used to develop the breed were the large red and brindle cattle of Normandy and the red cattle of Brittany in France. At one time all of the cattle of the Channel Islands were known as Alderneys. Eventually, laws prohibiting the importation of cattle from the continent or exchanging them between the islands of Guernsey and Jersey were passed and two distinct breeds developed. The animals on Alderney, Sark, and Guernsey became known as Guernseys and the cattle on Jersey Island became known as Jerseys.

The animals of the Guernsey breed are a shade of fawn with clearly defined white markings. Black and brindle markings are objectionable. The skin should show a yellow pigmentation. The

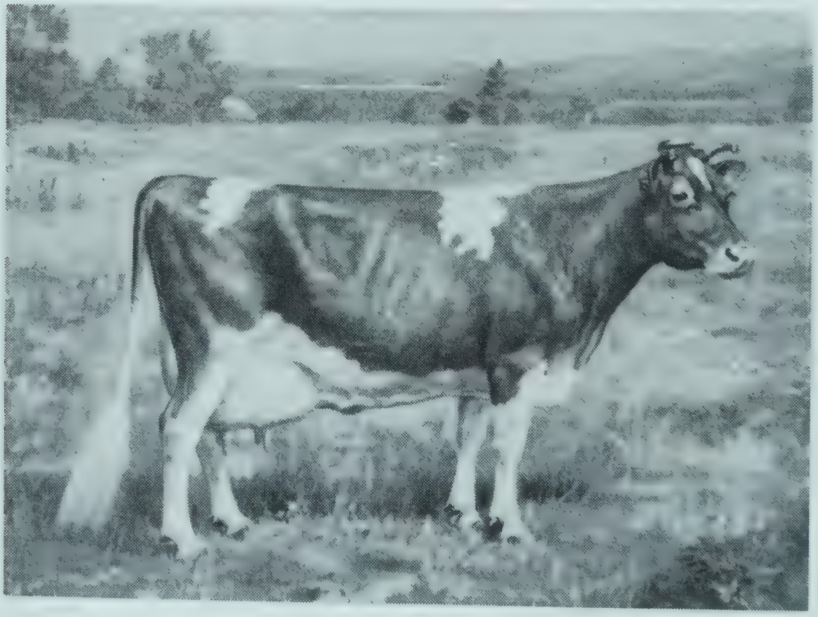

Fig. 13. The ideal type Guernsey cow. (Courtesy The American Guernsey Cattle Club.)

horns incline forward, are refined and medium in length, and taper toward the tips. They are small and yellow at the base. The mature cow weighs about 1,100 lb. Guernseys are alert but not easily excited. They are only fair grazers, especially on poorer pastures.

The milk, which averages 4.9 per cent butterfat, is much yellower in color than that of the other breeds. Guernsey milk, which is produced under certain rather strict regulations may be marketed under the "Golden Guernsey" trademark. The production and sale of milk under the trademark is supervised by Golden Guernsey, Inc., a subsidiary of the national breed association. This milk generally sells at a premium over regular milk. A royalty must be paid for the use of the trademark, but this money supports the supervisory and sales promotional activities which are carried on.

The first cattle imported into the United States were brought into Massachusetts in 1830. Importations were not numerous, however, until after 1870. This breed has been popular in market milk areas, particularly in the northeast and the North Central States.

The breed association is The American Guernsey Cattle Club, Peterborough, New Hampshire. This organization has been particularly effective in its work in capitalizing on the natural yellow color of Guernsey milk. No other breed has been able to market its milk under a trademark so effectively.

Holstein-Friesian Breed. The Holstein breed, as it is commonly called, is the most numerous dairy breed in the United States. Its popularity has been increasing at the expense of the other breeds, principally because of the emphasis put on decreasing the amount of fat in the human diet during the past several years.

The Holstein breed was developed in the northern part of the Netherlands, particularly in the province of Friesland and in the neighboring provinces of northern Germany. The development of this breed probably took place over a period of 2,000 years. These cattle long have been known for their large size and high yield of milk. They are phlegmatic and docile. They are excellent grazers on good pasture but only fair on moderate to poor pasture. The color pattern is varying proportions of black and white, with markings being clearly defined, and a white switch. There were some red and white animals in the early history of the breed. Occasionally, a red and white animal will be produced from black and white parents that carry the red factor as a recessive. Red and white animals cannot be registered in the United States. The horns incline forward, are incurving and refined, and taper toward the tip. The mature cow

Fig. 14. The true type Holstein-Friesian cow. (Courtesy Holstein-Friesian Asso. of America.)

should weigh about 1,500 lb and is a relatively refined animal with pronounced dairy qualities.

The large volume of milk produced by the breed now averages approximately 3.7 per cent butterfat. During the past 20 years Holstein breeders have been very successful in raising the test of Holstein milk. The national average is now about 0.2 per cent higher than it was in 1938. This success may be partly responsible for the present popularity of this breed. It also illustrates what breeders as a group can accomplish in improving their livestock.

The first importations into the United States were made in 1795. Beginning in 1870, heavy importations were made each year until 1887. Since 1905 very few Holsteins have been imported because of the prevalence of foot and mouth disease in Europe.

Two organizations for the registration of Holstein cattle were formed in this country. In 1885 The Holstein Breeders Association of America (originally called Association of Thoroughbred Holstein Cattle) and the Dutch Friesian Association of America were combined to form the present Holstein-Friesian Association of America, which is located at Brattleboro, Vermont. The association has sponsored sound extension and research programs over the years. This breed has been increasing in numbers all over the northern part of the United States, but gains in the South have been smaller. This difference appears to be due to the fact that the Holstein cannot stand

the hot weather in the South as well as the Island breeds. Through efforts of the breed association and individual breeders, many Holsteins have been sold in recent years to Central and South America. The milk of this breed is suited for both fluid and manufacturing purposes.

The Jersey Breed. As was indicated previously, the Jersey breed was developed on the Island of Jersey, the largest of the Channel Islands. In 1789 a law was passed which prohibited the importation of cattle onto the island except for immediate slaughter. The breeders on the island made intensive efforts to improve their cattle in both type and butterfat producing ability. A system of shows and a scale of points similar to our score card were originated in 1834. Production testing was started in 1912. Through these intensive efforts, a small, refined, uniform, and efficient cow, which produces high testing milk, was developed. Jerseys are very nervous and react quickly to both good and bad treatment. They are excellent grazers even on poor pasture.

Colors include various shades of fawn, either with or without white markings. The horns are inclined forward, are incurving, small at the base, refined, medium length, and tapered toward the tips. A mature Jersey cow normally weighs about 1,000 lb. The American Jersey is somewhat larger than the Island Jersey. The difference appears to be due to a difference in feeding programs. Heifers of this breed develop more rapidly than those of any other breed. Photographs of Jersey cows are given in that section of this chapter which discusses type classification.

Jersey milk averages about 5.3 per cent butterfat and is rich in color. Over a period of many years it has been considered the ultimate in milk for home consumption. During recent years, however, it has lost some of its popularity, owing to the increasing aversion to high fat diets.

The first Jerseys were imported into the United States in 1850. Between 1870 and 1890 a relatively large number of animals were imported. Since that time many animals have been imported each year except during the war years. Jersey cattle are found all over the United States and are particularly numerous in the South. Animals of this breed apparently do much better under southern temperatures than many of the other breeds.

The registry organization for this breed is The American Jersey Cattle Club, Columbus, Ohio. This organization has been very active in promoting production testing and type classification.

The Purebred Dairy Cattle Association. Membership in this organization, which was formed in 1940, includes representatives from those organizations which register purebred dairy cattle. Its purpose is to carry out various types of activities which will stimulate the improvement of purebred dairy cattle and the dissemination of information which will help in the expansion of the purebred dairy cattle industry.

Accomplishments for which this organization can take credit are:

1. Uniform score card.
2. Uniform rules for official testing.
3. Show classifications for each breed at fairs.
4. Rules and regulations governing artificial insemination in purebred dairy cattle.
5. Code of ethics for public and private sale of cattle.

Choice of a Breed. Many factors should be considered in the choice of a breed of dairy cattle. No one breed of dairy cattle is basically better than any other breed. There are greater differences between animals within a particular breed than between breeds. This does not mean that the selection of a particular breed is not important, however. Actually the choice is very important and sometimes means the difference between success and failure. The problem is to carefully weigh all the factors involved and then to select the breed which most nearly fits the situation on a particular farm. The more important of these factors are discussed below.

MILK MARKET. The market available for the sale of milk is an important factor in the selection of a breed. Where there is an adequate differential for higher testing milk, the higher testing breeds may find a place. The higher testing breeds also have a place where milk can be sold as a special milk at a premium price. This is particularly true for milk sold as Golden Guernsey and All-Jersey. If the fat differential is low, it ordinarily pays to have a breed which will give the greatest total yield of milk. The lower testing breeds produce milk which is more satisfactory for most manufacturing purposes. Although a few milk dealers like to sell milk which is high in both butterfat and solids-not-fat, most of them prefer to use milk from the lower testing breeds, because of the lower purchase price. Because of its beneficial effect on milk flavor, homogenization has stimulated this trend.

PERSONAL PREFERENCE. Some people seem to be more successful with one breed than with another, because of a personal preference. Such a preference usually results from boyhood experience with a

particular breed or from subsequent work with it. Some individuals become so prejudiced that they cannot see the virtue of another breed. Many dairymen, as a result of such loyalties, have tied themselves down to a poor herd of cattle because the animals belonged to a particular breed. These dairymen are oblivious to the fact that their herds of dairy cattle are inferior and cannot provide them with a reasonable living.

PREDOMINATING BREED IN THE COMMUNITY. Although conformity is not always a virtue, there often is considerable merit in keeping the same breed of cattle as one's neighbors. A breeder of purebred cattle can profit by discussing breeding problems with others in a local breed organization. Breeders in certain counties have conducted very successful consignment sales. Other groups have made their county or area known nationally as an excellent place to purchase purebred animals of a certain breed. This reputation has resulted in considerable extra income from the sale of breeding stock at good prices.

CLIMATE. Everything else being equal, one probably would select one of the lighter breeds for hot climates and one of the heavier breeds for cold climates. Jerseys and Guernseys can stand higher temperatures better than Holsteins because they can get rid of body heat more easily. Holsteins, because of their black color, absorb more heat from sunlight than light colored animals and thus suffer more in hot weather. Large animals can stand cold temperatures a little better than the smaller breeds because they lose heat less rapidly. In colder climates, however, such differences are of little practical importance.

BEEF-VALUE OF ANIMALS. Beef value is a poor basis for selecting a dairy breed. It costs money to produce the extra beef and it costs money to maintain it over a period of years. The animal that generally makes the most profit is the one with the greatest dairy conformation. This basis for selecting a breed is much sounder.

EARLY MATURITY. Raising dairy herd replacements is an expensive although usually necessary part of a dairy farm operation. In general the larger breeds require a longer time to reach maturity and the feed cost is usually greater. More animals must be raised to maintain a herd. This situation would not exist, however, if the animals remain longer in the producing herd. A dairyman also has to wait longer before beginning to get a return on his investment. Although early maturity is not the most important factor in selecting a breed, it should be given due consideration.

VIGOR OF CALVES. In general, calves from the larger breeds are

more vigorous and easier to raise than Jersey or Guernsey calves. Under good management, however, calves from these two breeds can be raised without difficulty. It is only under unfavorable conditions that one should be particularly concerned about this factor in selecting a breed of cattle.

EFFICIENCY IN DIGESTION AND UTILIZATION OF FEED. All breeds are about equally efficient in the digestion of feed. This fact also holds true for animals within a breed. The big difference is in what an animal does with the nutrients that are absorbed. One animal will be very efficient in converting nutrients into milk, whereas another will put more into body condition. One animal will have a high metabolic rate and convert a considerable quantity of nutrients into heat. Another animal will convert less into heat. There is no appreciable difference in the ability of one breed to consume proportionally greater quantities of readily available forage than another. There is much greater difference between animals within a breed than between breeds.

Judging Dairy Cattle. There are two general bases for evaluating the physical characteristics of purebred dairy cattle. Type classification compares an animal to a theoretically perfect specimen of the breed and assigns a rating. Show ring judging, as practiced at national and regional shows and at state and local fairs, places animals in classes of similar age, breed, and sex in order of excellence. Although there are modifications of these two systems, the basic facts are as given.

The general purpose of type evaluation is to encourage the breeding of dairy animals that are both functional and beautiful. In general, animals with higher type ratings produce more milk. Well-attached udders are less subject to injury and mastitis infection. Strong legs hold up longer than weak legs and feet. In addition to these items, a good looking cow sells for more money than a poor type cow. An attractive cow also creates more interest on the part of the owner or herdsman and results in better feeding and care and thus more profitable production.

TYPE CLASSIFICATION. This breed-improvement program is sponsored by the various breed associations, and the classification is done by an inspector hired by the association. This person is a qualified judge and is selected on the basis of his ability. In general, all animals in a herd over a certain age are rated on the basis of the official scale of points. The official rating is recorded by the breed association and usually is indicated on the registration certificate.

The owner is given information on the strong points and weaknesses of each cow. This information is invaluable in selecting herd sires and in evaluating a breeding program.

Figures 15 through 19 give examples of a Jersey cow falling into each classification rating and show what each classification means in terms of type.

SHOW RING JUDGING. In show ring judging the judge compares all members of a class of cattle but does not arrive at a numerical rating. He simply lines up the animals in order of perfection. Class winners within the breeds then compete for championships and grand championships within each sex.

In all of this work the score card serves as the guide, even though it is not actually used in the show ring. The main factors considered are general appearance, dairy character, body capacity, and mammary system. Each of these items is explained by material from the 1957 revision of The Purebred Dairy Cattle Association Unified Score Card as given in the appendix. In judging one must keep in mind differences due to age, stage of lactation, sex, and breed. One must know where the various parts of a cow are, how they should be formed, and how they should blend together. One also must be able to recognize and evaluate defects. A diagram showing names and locations of parts of the dairy cow is given in Fig. 20. A student should become familiar with all of this material before starting to

Fig. 15. An "excellent" cow. (Courtesy The American Jersey Cattle Club.)

Fig. 16. A "very good" cow. (Courtesy The American Jersey Cattle Club.)

Fig. 17. A "good plus" cow. (Courtesy The American Jersey Cattle Club.)

Fig. 18. A "good" cow. (Courtesy The American Jersey Cattle Club.)

Fig. 19. A "fair" cow. (Courtesy The American Jersey Cattle Club.)

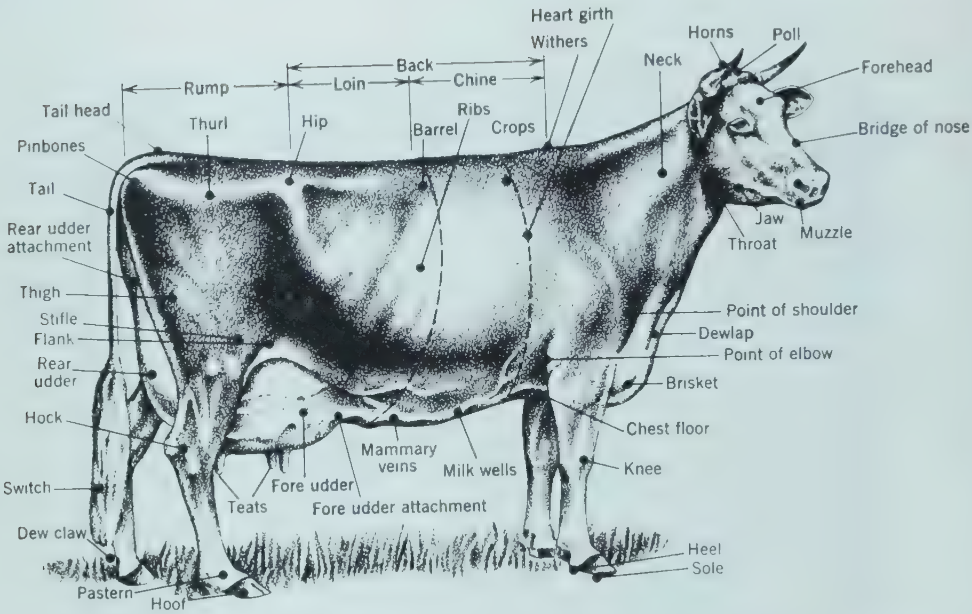

Fig. 20. Parts of a dairy cow. (Courtesy The Purebred Dairy Cattle Asso.)

judge dairy cattle. Judging ability, however, comes only with experience.

QUESTIONS

1. What is meant by a breed of cattle?
2. What is a grade animal?
3. What is a purebred animal?
4. What is a registered animal?
5. Where did each of the dairy breeds originate?
6. Give the mature weight, color, and physical characteristics of each dairy breed.
7. What is the average butterfat test and color of the milk of each breed?
8. Give the highest milk production record in the United States and the breed of the cow which made it.
9. Give the highest butterfat production record in the United States and the breed of the cow which made it.
10. What is The Purebred Dairy Cattle Association, and for what purposes was it organized?
11. Give five major accomplishments of The Purebred Dairy Cattle Association.
12. What factors should be considered in the choice of a dairy breed?
13. What is meant by show ring judging?

14. Why are breeders of purebred dairy cattle interested in type?
15. What is type classification and what is the purpose of it?
16. Who sponsors type classification?
17. What are the principal divisions of the unified score card for cows? For bulls?

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CHAPTER **6**

Dairy Cattle Breeding

The genetic ability of a cow to produce milk is determined by factors which she inherited from her sire and dam. External factors such as feed, care, disease, and environment also influence production. The amount of milk actually produced by a cow is the result of an interplay of genetic and external factors.

Principles of Inheritance. In the normal (somatic) body cell, each nucleus contains a certain number of *chromosomes*, which are filament-like structures composed of chromatin material. Along the chromosomes are located units of inheritance called *genes*, which by chemical means control the development of details of color, structure or form, and function. Characteristics of one generation are carried to the next by means of *sex-cells*—the *ova* of the female and the *spermatozoa* of the male. These are single cells (gametes), each of which has a nucleus containing one-half the number of chromosomes and genes carried by a body cell.

In the formation of sex cells, the chromosomes which come from the male parent pair with those which come from the female parent. Subsequently, two cell divisions rapidly follow one another, but the chromosomes divide only once. In each cell division the two members of each pair of chromosomes separate at random and pass to the new cells. As a result of these cell divisions (meiotic) the number of chromosomes in the ovum and in the spermatozoon is one-half of the number in the cells of the parents. Because along with the pairing of maternal and paternal chromosomes exchange of portions of these chromosomes may occur, a sex cell (gamete) formed by

an individual will usually contain chromosomes which are a mixture of maternal and paternal chromosome segments. If fertilization takes place after mating, one spermatozoon enters one ovum, the nuclei unite, and the chromosome number is returned to the original number. Thus a new organism, which received half of its genetic material from each parent, is initiated. The goal in plant and animal breeding is to pass on the largest possible number of desirable genes to the next generation and to eliminate or discard as many as possible of the undesirable ones.

The simplest form of inheritance exists when a certain trait or character is determined by a single pair of genes. One example of this is the polled condition in cattle, which is shown in Fig. 21.

In this example polled is called a *dominant* trait because the animal has no horns regardless of whether it carries the genes *PP* or *Pp*. The horned condition is called a *recessive* trait because it does not show up if a dominant (*P*) is present. When both genes or factors are alike (*PP* or *pp*) they are said to be *homozygous*. If the factors are unlike (*Pp*) they are said to be *heterozygous*. Dominant genes, which only partially mask effects of corresponding members, are said to exhibit *partial dominance*. When genes at one position prevent the expression of genes located at another position on the same chromosome or on another chromosome, they are said to show *epistasis*. The closer different genes are to one another on the same chromosome, the more likely they are to be transmitted together to

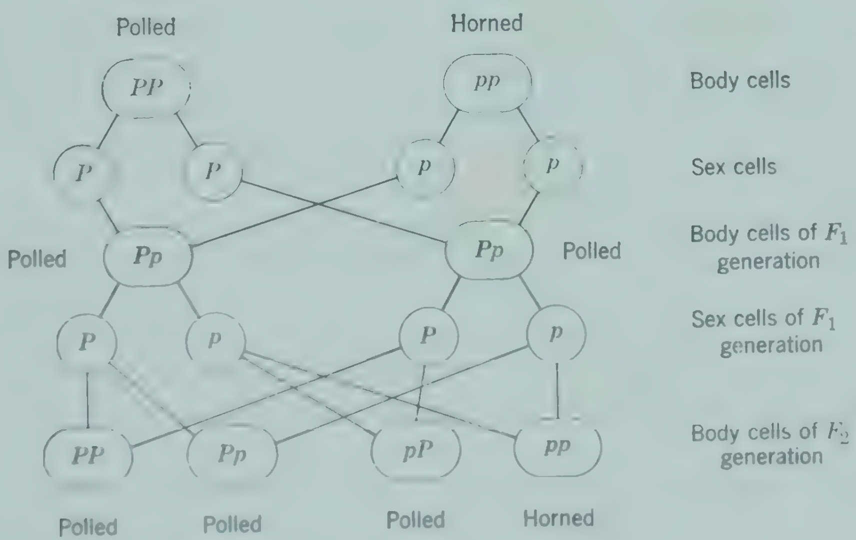

Fig. 21. This diagram shows how a simply inherited trait is transmitted to the next generation.

the next generation. Such a phenomenon is known as linkage. The farther apart genes are on a chromosome the more likely they are to separate and assort independently. During sex cell formation a pair of chromosomes sometimes breaks at certain places, and the chromosome segments exchange places along with all of the genes involved. This phenomenon, called *crossing over,* increases genetic variation.

The terms *genotype* and *phenotype* frequently are used in connection with animal breeding. Breeders of dairy cattle well know that traits exhibited by the parents frequently are not seen in the offspring, and vice versa. In light of the previous discussion, the reason for this is not a mystery. What we actually see in an animal (or in the way it performs) is called the phenotype. It is the result of the genetic make-up conditioned by environmental factors. The actual genetic composition of the animal is called the genotype. The inability to know the genetic make-up of animals accounts for the uncertainties which are associated with the endeavors of even the most skillful animal breeder.

There are 30 pairs of chromosomes in cattle. One of these pairs is referred to as the sex chromosomes. These sex chromosomes are of two types, one being designated as the X and the other as the Y chromosome. These special chromosomes are involved in *sex determination* at fertilization. An individual having 2 X chromosomes becomes a female; one having an X and a Y becomes a male. It is now known, however, that in some organisms sex genes which produce a tendency toward maleness or femaleness are located on chromosomes other than the sex chromosomes and thus may modify sexual development or differentiation. In cattle, traits due to genes located on the X chromosome follow a crisscross inheritance pattern. The male transmits sex-linked traits to his grandson through his daughters, not through his sons. This is called *sex-linkage.*

Lethal Characters. These are factors which result in premature death under good environmental conditions. Such factors usually are inherited but not always. All breeds of dairy cattle have such defects, but the frequency varies. Lethals include bulldog calves, absence of legs, impacted molars, missing leg bones, lameness, muscle spasms, and fused nostrils. These characters usually are due to a homozygous recessive. In an affected herd, there generally is a ratio of about 7 normal calves to 1 affected. Lethals have resulted in heavy losses in certain herds and in certain breeds. Accurate records should be kept of their occurrence so that steps can be taken to eliminate carriers.

Practical Use of Genetic Principles. Color inheritance is a good example of the practical use that can be made of a genetic character. The various dairy breeds have been developed so as to be characterized by certain color patterns. In other words, the color pattern is a trademark of the breed. Quite frequently several pairs of genes interacting in various ways are involved. In Holsteins, the black is dominant to red. When a heterozygous bull (*Bb*) is used in a herd which has cows that are heterozygous, some red offspring usually result. Purebred animals which are red and white cannot be registered. The black and white spotting of Holsteins is determined by other genes.

Milk and butterfat production are for the most part inherited independently of each other. Each is determined by a large number of factors which affect various body functions. Actually, it should be realized that such factors as body size and capacity, feed consuming ability, endocrine function, and udder size are all part of the inheritance of milk and butterfat secretion. Because the inheritance of milk and butterfat production is so complicated, improvement through breeding requires skill, patience, sound judgement, and good fortune. There are relatively few breeders who have made really significant contributions to dairy cattle improvement. These few, however, have contributed greatly to the quality of many generations of cattle owned by other breeders.

Systems of Breeding. The systems used in the breeding of dairy cattle generally are divided into two broad classifications, *outbreeding* and *inbreeding.* These are divided further, as will be discussed later. Each system has both strong points and weaknesses.

OUTBREEDING. Outbreeding is the mating together of individuals less closely related than the average of the group from which they come. Outbreeding is divided into *outcrossing* and *crossbreeding.*

Outcrossing is the mating together of unrelated members of the same breed. Considerable progress can be made with this system if standards are adopted for the selection of breeding stock and for culling. Centralized artificial breeding generally results in this type of breeding program. By the continuous introduction of genes for high production into the herd, its level of production should gradually rise.

Crossbreeding is the mating of animals belonging to different breeds. This type of breeding program has been used very successfully in the production of poultry, swine, and many fruits and vegetables. Hybrid corn is an outstanding example. When plants and

animals which are unrelated are crossed, the first generation offspring frequently are more vigorous, grow more rapidly, and produce more than the parent lines. This phenomenon is called *heterosis* or *hybrid vigor.* Such plants and animals are usually of little value for further breeding, however, because the various factors that were combined in the cross *segregate* out in the next generation and give all sorts of combinations with respect to color and producing ability.

Crossbreeding has been used to some extent with dairy cattle. The Dairy Cattle Research Branch of the U.S. Department of Agriculture reported favorable results from its use with respect to milk production. Crossbreeding has been used much more extensively with grade cattle than with purebreds. One of the most common examples has been the insemination of grade cows with semen from the best available bull, regardless of breed. Because the purebred bull is used in most crossbreeding, purebred herds will continue to be the basis for herd improvement through this system. For this reason, purebred herds must be maintained and an attempt made to improve them.

INBREEDING. Inbreeding is the mating together of individuals more closely related than the average of the group from which they come. Inbreeding can range from intense inbreeding to mild inbreeding. Inbreeding tends to intensify or fix certain characteristics and is particularly useful for forming distinct families. Crosses between such families frequently produce very desirable results. Inbreeding is divided into *close breeding* and *line breeding.*

Close breeding is the mating together of individuals such as brother to sister, sire to daughter, and son to dam. *Line breeding* is a milder form of inbreeding in which one attempts to maintain a high degree of relationship to some particularly desirable ancestor. Most herds which have been closed to outside blood for several years will be somewhat inbred. Animals which carry 50 per cent or more common ancestry are said to be close bred, whereas those showing 25 to 50 per cent common ancestry are said to be line bred. Inbreeding was used extensively in establishing most of our breeds. Various factors became homozygous and thus were established so that they could be carried down through hundreds of years. This fact is particularly true for such characteristics as color pattern and conformation. When desirable characters are made homozygous the results are very worthwhile. When undesirable characters are made homozygous, however, the results are bad. Lethal defects, infertility, and other weaknesses are particularly likely to become troublesome when closely related animals are mated. When such factors are not present, however, animals resulting from such matings are just as normal as

those from unrelated matings. Because of the possibility that undesirable characters may show up with close breeding, line breeding is followed much more extensively.

Developing a Breeding Program. Although purebred dairy animals constitute only a relatively small percentage of the total dairy cattle in the United States, they can take much of the credit for high levels of production attained in both purebred and grade herds. The reason for this is that purebred bulls of a particular breed generally have been used over a period of years in most good grade herds. As a result many grade herds produce just as well as many purebred herds. It is impossible, therefore, to visualize a real breeding program with dairy cattle which does not depend on purebreds. Crossbreeding and upgrading are really the use of the results of another person's breeding program.

It is very difficult to outline the essentials of a sound breeding program. It is much harder still to successfully carry one out. The steps that one might follow in developing a breeding program are as follows:

1. Select a suitable breed of cattle.
2. Select or purchase the best possible cows from the breed selected with due consideration being given to health, age, price, etc.
3. Select the breeding program or programs which offer the greatest hope for herd improvement.
4. Evaluate strong points and weaknesses of the cows owned.
5. Obtain the services of the bull(s) which offers the greatest promise of strengthening the most serious weaknesses of the herd and making the greatest improvement in type and production. Due consideration should be given to health, age, and price.
6. Enroll in that program of production testing which best meets the needs of the breeding program.
7. Carry out that program of type evaluation which best meets the needs of the breeding program.
8. Establish minimum standards for type and production as a basis for culling. These standards must be held to very strictly and raised as progress permits.
9. Establish reasonable standards for freedom from disease, temperament, and ease and completeness of milking and hold to them in as far as possible.
10. Follow feeding and management practices which will permit all animals to exhibit at least to an optimum degree their inherited potentialities.

Most of these items have been discussed in various parts of this text. The procedures followed and the standards selected will depend on the resources of the individual breeder and the quality of the herd with which he is working. A breeder must keep in mind that what an animal looks like and how it performs is not as important as what he or she transmits to the next generation. The objective in a breeding program is to *eliminate* the most undesirable individuals and to *mate together* selected individuals considered to possess desirable characteristics to the highest degree.

In many cases uniformly desirable type and high production have been observed in the offspring of a certain cow or bull in a particular herd. Strains or families developed from such individuals have become very popular in a region or even nationally. A good example of the development of an outstanding cow family is provided by the records of the University of New Hampshire Dairy Herd. UNH Perfection Echo 1978325(VG) was born March 21, 1938. In 12 lactations on official test, twice-a-day milking, she produced a total of 200,677 lb of milk, 3.9 per cent, 7,742.4 lb of butterfat in 4,119 milking days and was barely 16 yr of age. Her highest record was in Advanced Registry at the age of 8 years, 10 months, when she produced 23,070 lb of milk, 4.1 per cent, 955 lb of butterfat.

In addition to this outstanding production record, Echo had 7 daughters which lived to enter the milking herd. Of these, 5 made lactation records which exceeded 24,000 lb of milk and 1,000 lb of butterfat, all on twice-a-day milking. The remainder of the daughters produced nearly as much as these. The granddaughters and their offspring have inherited the same outstanding producing ability. The descendents of Echo were high producers regardless of the bloodlines of their sires. Thus, a nationally known family of Holstein cattle traces to a single cow who was able to transmit the ability to produce large quantities of milk and butterfat to succeeding generations.

Evaluation of a Breeding Program. The progress being made in any breeding program must be measured continually. A superior dairy cow must be a high producer and have acceptable or better type. In addition, she must be a good breeder, have an udder which is not subject to injury, and produce offspring which are normal, healthy, and high producers.

Production testing is the first measure of the success of a purebred breeding program. If records are to be fully accepted by the breed association and other purebred breeders, one of the official pro-

grams must be used. The only way in which a breeder can fully capitalize on a successful breeding program is to sell breeding stock at favorable prices. He cannot do this with unacceptable production records. The various systems of production testing are discussed in Chapter 10.

Type is the second criterion of the success of a breeding program. As discussed in Chapter 5, this factor can be evaluated by means of type classification and show ring judging. Official type classification is probably the most reliable measure of type. It is based on a mathematical evaluation using the score card. The individual itself is considered instead of compared. Show ring winnings also are given considerable attention in pedigrees and advertising. They must be evaluated on the basis of the competition at the particular show. The poorest animal in certain shows may be better than the best in others.

Information on other factors can be obtained from herd records. The age of the cow when she left the herd, the reason for leaving the herd, the number of offspring, disease problems, etc., are all of value in evaluating a breeding program. Evaluation is one of the reasons for keeping herd records, as discussed in Chapter 10.

Pedigrees. A pedigree is a record of an animal's ancestry along with certain pertinent information such as production records, type classification, and show ring winnings. The record is placed on a special form so as to show the sire on the upper half of each bracket and the dam on the lower. The parents of any particular animal are on the lines immediately to the right of the line on which its name appears. Pedigrees giving various amounts of information are given on registration certificates, in herd books, in sales catalogs, etc.

A pedigree can be very helpful if properly written, or very misleading if improperly done. A well-written pedigree is complete and accurate. For females it should give all records of production, both poor and good. Under both sires and dams, records for all daughters should be given. All type classification ratings should be given—not just the high ones. Winnings at minor fairs should not be shown, because they may be very misleading. Some breeders and certain sale managers have written pedigrees which have lead inexperienced purchasers to think that mediocre cattle were very outstanding. This practice is now relatively rare. Reputable breeders and sale managers are very anxious to present an honest picture of an animal's worth. The reputation and continued success of both depend on animals measuring up to their pedigrees.

MALE **U N H Dean 1325559** **Cat. No. 5**

Born January 21, 1958

His dam, Liza, is the highest record fat daughter of U N H Perfection Echo, and regarded by many as the nearest of all the daughters in likeness to the "old cow." Liza is a Gold Medal dam in her own right, the middle of a 3 generation group averaging 1063 fat 2X. U N H Dean combines Echo, Togus and Golden Tidy.

Consigned by:
UNIVERSITY OF
NEW HAMPSHIRE
Durham, N. H.

Bangs Certified

GOFSON TIDY TOGUS 1213947
Very Good - 87
A full brother to:
Gofson Ruby Togus (VG)
2y8m 365d 2X 14530 4.3 618

UNH MIKE LIZA
Very Good - 87 Gold Medal dam
8y 4m 365d 2X 26161 4.3 1131
7y 1m 365d 2X 24360 4.6 1116
11y10m 365d 2X 24746 4.1 1020
5y11m 349d 2X 23495 4.2 993
5y11m 305d 2X 22385 4.2 936
Former Natl. records 305 & 365d
9y 8m 329d 2X 23025 4.0 920
Life production to date over
200,000 milk 4.15% 2X
Full sister 5 times over 1000F. 2X
Dam of:
UNH Schoolmaster (GM-Ex)
UNH Count Prospera (GP)
6y11m 365d 2X 25937 4.3 1104
Mass. State Champion All Ages
UNH Marathon Conqueror (SMP)
UNH Ormsby Sensation Squire (VG-87)
UNH President Belle
2y1m 322d 2X 15036 3.8 568
UNH President Anita (GP)
3y9m 365d 2X 21041 3.9 812

DAUNTLESS TOGUS DIRECT 821505
Gold Medal - Excellent

51 dtrs. ave.	15250	3.81	581
46 dtrs.	15192	3.84	583
46 dams	13102	3.83	502
Increase	2090	.01	81

First sire of breed to have 4 dtrs. over 1000 fat 2X (from 1015 - 1147)

GOFSON LOIS TIDY 3169993
Very Good

5y	365d	2X	16700	3.7	621
4y	365d	2X	15250	3.7	569
6y	298d	2X	14374	3.9	561
2y	365d	2X	13597	3.8	510
3y	305d	2X	11106	3.8	423

Dam of:
Gofson Olive Levi (GP)
3y 365d 2X 16734 3.5 591
Gofson Ruby Togus (VG)
2y 365d 2X 14530 4.3 618
(Full sister to Gofson Tidy Togus)

NJES CONQUEROR FLORES MIKE
Silver Medal Prod. - Very Good
32 dtrs. ave. 13222 3.85 509
4 dtrs. with 848 - 929 - 1056 - 1131 fat, 2X.
4 dtrs. over 100,000 milk, 2X.

UNH PERFECTION ECHO (GM)
Very Good - 87 at 16 yrs. of age
EX Dairy C - Body Cap. Rump.
8y10m 365d 2X 23070 4.1 955
10y 0m 364d 2X 19818 4.6 904
Life prod. 2X 203088 3.9 7841
5 daughters over 1000 fat 2X
2 daughters over 200,000 milk 2X
2 others over 145,000 milk 2X
She and 7 daughters have produced 1,082,000 lbs. milk to Apr. 1, 1958.
Breed's first Gold Medal dam of 2 Gold Medal daughters.
Heads breed's 1st 3 generation group of Gold Medal dams.

BAKER FARM DAUNTLESS
Gold Medal - Excellent
114 dtrs. ave. 12050 3.94 475
Diff. 108 pr. —430 +.26 +15
Daughters to 963 fat 3X
25 over 100,000 lbs. milk, 3rd for the breed.

DIRECT UNA TOGUS (VG)

8y	365d	2X	24065	3.4	829
7y	365d	3X	19226	3.6	689
7 lacts.			118215	3.4	4053

2 dtrs. over 129,000 milk with 759 fat 2X - 896 fat 3X

DUNLOGGIN GOLDEN CROSS TIDY (GM - GP)
Sire 3d Get Eastern States 1952

79 dtrs. ave.	14701	3.77	554
78 dtrs. ave.	14722	3.77	555
78 dams	13322	3.78	504
Difference	+1400	—.01	+51

Daughters to 983 fat 3X
Maternal brother GM-EX
Maternal sister EX—over 100,000

GOFSON IDA IMPROVER
Good Plus

6y	339d	2X	15094	3.8	574
5y	355d	2X	14635	3.9	572
7y	365d	2X	15392	3.7	564
3y	365d	2X	14341	3.5	508
8y	365d	2X	11670	3.8	441

NJES SENSATION CHARLOT CONQUEROR
Gold Medal - Excellent
90 tested daughters
79 dtrs. ave. 11340 3.89 441

NJES CHIEF ORMSBY COLINA FLORES (VG)
7y 365d 2X 15847 3.6 549
8y 365d 2X 14979 3.6 544

CARNATION INKA PERFECTION
15 dtrs. ave. 11490 3.55 408
Increase 11 pr. 550 3

UNH MATADOR BUTTER MAID
4y6m 330d 2X 16068 3.5 567
5y8m 347d 2X 15928 3.4 544
Maternal sister to:
UNH Everlasting Mod. (SMP-VG)

Fig. 22. A pedigree taken from a sales catalog. This bull calf sold for $5,400.

A pedigree of an outstanding bull calf is given in Fig. 22. Note the completeness of the records on the animals included, as well as the high level of production.

Selection of Breeding Animals. When selecting dairy cattle to be purchased or to be used in certain matings in a breeding program, a breeder usually rates each animal on the basis of milk production, type, and pedigree. In determining the overall value of an animal, the importance attached to each trait depends on the breeder's experience and what he is trying to accomplish. In general, however, production is considered to be more important than the other factors, because it is the purpose for which dairy cows are kept.

The selection of bulls presents a different set of problems than the selection of cows. Different factors must be considered in selecting young animals as compared to mature cattle. Real skill in the selection of good dairy cattle results only from a combination of experience and good judgement. A few of the factors that are generally considered in the selection process are discussed.

SELECTION OF FEMALE DAIRY CATTLE. Cows can be selected on the basis of their own milk-producing ability. If properly evaluated this is a good starting place. In order to evaluate all cows on the same basis, however, one must take into consideration all production records, the age of the cow when each production record was made, feeding and management conditions under which they were made, the number of times the cow was milked per day, the length of lactation, and the calving interval. The various breed associations now have factors which can be used to convert various types of production records to a twice-a-day milking, 305-day lactation, mature equivalent basis.

The evaluation of feeding and management conditions is a matter of judgement. It should be kept in mind that a cow that has made a moderately good record under poor conditions may be potentially a higher producer than one with a good record made under exceptionally favorable conditions. Experienced cattlemen frequently purchase good cattle at bargain prices from dairymen who do not realize the potential producing ability of the cattle they own.

When one is concerned with expensive purebred cattle, knowledge of the producing ability of the animal under consideration is not enough. One also should make use of all available information on the milk production of full and half-sisters from the same dam, half-sisters by the same sire, grandparents, and daughters if any are in production. Because full and half-sisters from the same dam

normally differ considerably in age and are few in number, and because an animal may have several paternal half-sisters of approximately the same age, these paternal half-sisters are valuable for indicating the probable breeding worth of an animal for milk production or other characteristics. The producing ability of daughters or the transmitting ability of sons would be the best possible measure of a cow's transmitting ability. Often, however, this information is not available when female dairy cattle are being considered for purchase or for use in a breeding program.

Although show ring winnings are not particularly useful to most breeders, except from an advertising standpoint, type evaluations are. It has been established that there is a positive relationship between good dairy type and high producing ability. Thus a dairy type rating is another way of evaluating producing ability.

In addition to its value as a record of the producing ability and type of an animal's ancestors and other relatives, a pedigree sometimes has particular significance because of the fame of certain well-known ancestors. Just as certain people take great pride in the fact that one of their ancestors came to this country on the Mayflower, or have their social standing established by the fact that they belong to a certain distinguished family, dairy cattle sometimes are valued very highly because a particular sire or dam is an ancestor, even though it may be several generations back. It is poor policy, however, to purchase an animal because of some remote ancestor. The ability to produce large quantities of milk and to transmit high producing ability is much more important. In the case of the female that has not yet come into production, the evaluation will have to be made on the basis of all the factors mentioned except the producing ability of the animal herself and the producing ability of offspring. The risk is somewhat great and often is reflected in the lower price brought by heifers at cattle auctions.

In selecting dairy cattle for purchase, a person has to set up standards for type and production. A minimum standard for production might well be the H.I.R. breed averages as given in Table 9. The minimum for type could be set as "good plus." Standards for both should be raised as financial resources permit. It should be kept in mind that a high-producing cow may return a high purchase price relatively quickly, but it may take years to upbreed a low-producing herd to a high level of production, and these results are not assured.

SELECTION OF BULLS. The selection of bulls carries much greater responsibility than the selection of cows, particularly if one bull sires 50,000 or more offspring by artificial insemination. For this reason

all available information must be examined in detail. Mistakes and errors in judgement can be very serious or even disastrous. In evaluating bulls, one normally considers the same factors as with cows, except that the ability of the bull to sire good milk-producers is evaluated. This ability is expressed in terms of a *sire index,* the most common types of which are given.

1. *The daughter average* is sometimes used as a measure of a sire's transmitting ability. The producing ability of the dam of each daughter is not considered.

2. *The daughter–dam difference* is used to evaluate a sire by indicating the amount that he increased or decreased the production of his daughters as compared to their dams. This method may or may not indicate the level of production of the dams on which the sire was used.

3. *The equal–parent index* is used to calculate a sire's capacity to transmit producing ability. Because it is assumed that the producing ability of the daughters is half way between the producing abilities transmitted by the sire and the dams, it is calculated as follows: sire index = 2 × average production of daughters — average production of dams.

4. *The daughter–contemporary herd difference* approaches the problem by substituting the actual herd average for the dam's average production in daughter–dam difference.

5. *The daughter–contemporary herd index* substitutes the actual herd average for the dam's average production in the equal-parent index.

In these two latter methods the actual herd average is used in an attempt to minimize the effect of feeding and management factors in the herd in which the production records were made. In a recent study in which all of these methods were compared, it was found that the simple daughter average was nearly as reliable as the equal-parent index or the daughter-herd index. There was not a marked superiority for any particular method, but the daughter-herd difference was slightly inferior to the other methods.

The term *proved-sire* is an important one as far as dairy cattle breeding is concerned. As used in the Dairy Herd Improvement Association program, a proved-sire record is tabuated for each sire as soon as production records for five or more dam-and-daughter pairs become available. The sire's record is revised or retabulated from time to time as production records are accumulated for additional pairs.

The fact that a sire is a *proved-sire* does not necessarily mean that he has increased the production of his daughters over that of their dams. It simply means that at least five of his unselected daughters have been compared to their respective dams in producing ability on a uniform basis. Most breed associations have a similar program for proving sires. In this type of program it is very essential that the comparisons used be "unselected." This term generally means that all daughters are compared with their dams and that all records of both are used. If the records to be used are selected on the basis of high production, the result may make the sire appear very much better than he really is. In general the reliability of a proving inceases with the number of daughter-dam comparisons.

In the case of young bulls one has to depend on promise rather than performance. For this reason a young bull frequently is "sampled" and then used relatively little until his daughters have been compared with their dams. These results are compared with those from other bulls sampled in a similar manner. If the bull is proven to transmit acceptable type and production, he is returned to service. If type and production are not acceptable, he should be discarded. In general the amount of use a sire receives increases in proportion to his reputation as a transmitter of high production and desirable type.

A good basis for selecting a sire is to consider the purchase as an investment of money. In making an investment one wants to get the greatest possible return consistent with a reasonable amount of safety. Thus a breeder should, with everything else being equal, invest in that bull which offers the greatest potential return on his investment. In general this means the purchase of the best available bull consistent with available resources, the quality and number of animals to be serviced, the level of feed and management under which the breeder's own herd is kept, and the opportunity for selling breeding stock at favorable prices. Thus the owner of a large, high-producing purebred herd can afford to pay considerably more for a bull than the owner of a small grade herd, and an artificial breeding cooperative can afford to invest more than most large breeders. No breeder, however, can afford to invest in a bull which does not show some promise of improving the level of production of the herd.

Registration of Purebreds. The first step in the registration of purebred animals is to record the name of the animal, the names and registration numbers of the sire and dam, the date of birth, sex, color

pattern (or photographs) or tattoo number, owner, breeder, etc., on a form supplied by the breed association. This application form is sent to the breed association with the appropriate fee. When artificial insemination was used, a form supplied by the technician at the time of service also must accompany the application for registration. When cows were bred by a previous owner or the bull was owned by another person, other forms giving the date of service and sire used may be required. Each form is signed by the appropriate person who certifies that the information given is correct. If everything is in order, the animal is registered in the herdbooks of the association, and a registration certificate is sent to the breeder. Dishonest practice in the registration of cattle can result in permanent loss of the privilege of registering cattle in the herdbooks of the association, cancellation of registration of animals which may have been registered improperly, and publicity on the case in the national publication of the breed.

Before purebred animals are registered they must be given a name by the breeder. Only one animal within the breed can have a particular name. In order to simplify the problem of naming animals and also to identify them with a particular farm or breeder, the various breed associations will, upon application, restrict the use of a certain name to a particular breeder. This name may be part of the name of the farm, the name of the breeder, or a name having particular significance in the area. This name is used in naming every animal to be registered by the breeder.

Many breeders also use part of the name of the sire in an animal's name. A smaller number also use a name from the dam. Thus, from the name of an animal it is possible in many cases to know the farm where it was bred, the sire, and the dam. This device is particularly useful in selling animals from better known bloodlines. Even the ordinary breeder, however, can benefit from a good system of naming purebred animals.

Artificial Insemination. The artificial insemination program was initiated in this country in 1938 in New Jersey by Professor E. J. Perry of Rutgers University. He studied the program in Denmark and decided that it would be of value in improving dairy cattle in the United States. Artificial insemination ranks with D.H.I.A. testing in its contribution to the general improvement of dairy cattle. Actually, it has had much wider acceptance than D.H.I.A. In 1958 over 6.6 million cows in this country (31 per cent) were bred artificially, and the number is increasing every year. Formerly, the

average dairyman was limited to the use of very ordinary bulls. Now he can have his cows serviced to some of the best bulls in the country. This advancement has resulted in tremendous improvement in the genetic composition of the dairy cattle in this country.

In reality, however, much of the value of this improvement is not being realized. Nutrition and management factors on many farms have been of such a level that genetic improvement has never had a chance to be exhibited. In such cases, high quality germ plasm is being wasted. In terms of herd improvement, artificial breeding is paying off fully only on those farms on which feed and management are not the limiting factors. In terms of other considerations, however, there are many advantages to artificial insemination and a few disadvantages. Some of the advantages and limitations are listed.

Advantages

1. Good sires are available to almost all dairymen, regardless of their resources.
2. The cost of artificial insemination service usually is cheaper than keeping bulls.
3. One or more cows may be kept with feed, labor, and space that would be required for a bull.
4. The dangers associated with keeping bulls are eliminated.
5. More complete and accurate breeding records are usually kept, thus resulting in better control of breeding.
6. Because fewer sires are needed, selection can be more intense.
7. The rate of genetic progress can be increased.
8. Spread of disease by the bulls is minimized.
9. The use of good bulls can be greatly extended.
10. Losses from infertile bulls on a particular farm may be reduced.
11. Bulls can be proved much more quickly.
12. Losses from using poor sires are minimized.

Limitations

1. Bulls must be carefully selected.
2. Good procedures and well-trained technicians are very essential.
3. A breeding program is difficult to carry out.
4. Sound business methods are necessary.
5. The sale of bulls for breeding purposes is greatly reduced.

Artificial insemination has had a very marked effect on bull prices. Exceptional bulls are sought after by the various studs and sale prices may run to many thousands of dollars. The value of ordinary bulls,

however, has been reduced to beef prices. Most purebred breeders no longer have a market for bulls for breeding purposes. This situation has prejudiced some breeders against the artificial breeding program. Most purebred breeders, however, have taken the attitude that any program which will lead to the improvement of dairy cattle is desirable and should be supported.

The development of artificial breeding has placed tremendous responsibility on sire selection committees. The use of a poor sire can have an adverse effect on the income of hundreds of dairymen. The use of an exceptionally good bull can be of great benefit. Most selection committees now evaluate all available information very carefully before making a decision on a particular bull. They look at the bull himself, study his pedigree, check the records and type of all daughters and their dams, and investigate the health records of the bull and the herd in which he is located. Breeding associations follow D.H.I.A. and breed association sire provings very carefully. Such records may locate a potential bull for the stud. Any delay in making an investigation may result in the bull's being purchased by another organization or in the payment of an excessive price.

Organization of artificial breeding systems vary from one area to another. Many are cooperatives with a strong central organization. Others consist of decentralized cooperatives with a jointly owned stud and processing center. In other areas a privately owned and operated corporation provides artificial breeding service. The success of any type depends on the cost and the quality of the service rendered.

Use of service is essentially as given below. When a cow has been fresh at least 60 days and is in heat, the dairyman notifies the local technician, giving the name or number of the cow and the hour when she was discovered to be in heat. There is usually a deadline for getting calls in for service for the day. If the cow was in heat in the morning, an attempt is made to inseminate her that day. If heat was discovered in the afternoon, the cow is placed on the list for the next morning. The dairyman usually fastens the cow in a stall in the barn and may indicate that she is to be inseminated by putting a red tag over her. The dairyman may indicate the bull to be used if there is a choice. The technician places one milliliter (ml) of diluted semen in the cervix and uterus of the cow, makes out a breeding slip like the one that is illustrated in Fig. 23, signs it, leaves a copy for the dairyman, and records the service on a record such as is shown in Fig. 41. He collects the service fee if one is due and moves on to the next farm on the list for the day.

BREEDING RECEIPT E 101750

New Hampshire-Vermont Breeding Association

Date of Breeding ________ Breed of Cow ________

Name of Cow ________

____

Registry No. ________ Tattoo ________
(Or ear tag if grade)

Was Cow identified by checking registration papers? ________
(Before resulting offspring can be registered, cow must be identified by checking registration papers.)

Owner ________

Address ________

Name of Bull ________

Registry No. ________

Was Frozen Semen Used? Yes____ No____ Breeding Fee ________

Service Number ________ Date of Previous Service (if any) ________ Bull Used ________

New Hampshire-Vermont Breeding Association

I hereby certify that I am a duly authorized agent of the above named business and as such have the authority to issue this receipt which is given as evidence of services rendered and also a certification of date of service and identity of semen used for service of animal identified hereon.

Signed ________
INSEMINATOR

The original copy of this receipt must be given to owner at time of service and must accompany Application for Registry or Birth Report, unless cow is sold before the calf is born, in which case it must be sent to the breed registry organization with the Application for Transfer of ownership.

USE INDELIBLE PENCIL OR INK

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Fig. 23. A typical breeding receipt which is to be completed by the technician at time cow is serviced. (Courtesy New Hampshire-Vermont Breeding Asso.)

Copies of all breeding slips are sent to headquarters for statistical purposes, which include the calculation of breeding efficiency.

Production and processing of semen are carried on at the headquarters of the organization or at a bull stud located elsewhere. Much semen now is purchased from other breeding cooperatives and from private individuals and corporations. Semen usually is collected from each bull once or twice a week, with different bulls being collected on different days. Semen is collected in an artificial vagina, taken to the laboratory, checked for quality, and if up to standard, diluted, cooled, packaged with a refrigerant, and shipped to the individual technicians.

A common diluent is composed of a citrate buffer solution, skim milk, and an antibiotic. The rate of dilution may vary from 50 to 100 or more, depending on the original sperm concentration and the quantity needed. Very rigid rules to prevent the making of mistakes in the labeling and use of semen from each bull are followed. These include the use of different colored labels for each breed, the checking of numbers by more than one person, and the use of routines which help to prevent mistakes. With the latest techniques, fresh semen can be used successfully for about 5 days after collection. This development extends the usefulness of bulls and gives the dairyman a greater choice of sires on any particular day.

Frozen semen is now used in many areas. Although it has many advantages, it also has some serious limitations. Both are listed below.

Advantages of Frozen Semen

1. Gives dairymen greater choice of sires.
2. Extends usefulness of exceptional sires, even long after death.
3. Frozen semen keeps indefinitely.
4. Semen may be shipped all over the world.

Disadvantages of Frozen Semen

1. Very high cost of processing, shipping, and storage.
2. Greater care required in processing and using frozen semen.
3. More difficult to control spread of disease through semen.
4. Reduction in conception rate may result.
5. Semen from certain bulls cannot be frozen successfully.

Attempts are being made to dry semen without destroying sperm viability. Results to date, however, have not been successful. Such a procedure could have the advantages of frozen semen but without

the high costs of refrigeration and shipping. It appears likely that most progress in the immediate future will come from increasing the usable life of fresh semen, reducing the need for refrigeration, and improving procedures for processing and handling frozen semen. Much research is being carried out in these areas and continued developments can be expected.

QUESTIONS

1. What determines the limit to a cow's ability to produce milk and butterfat?
2. Explain how chromosome numbers are maintained constant from one generation to the next.
3. What is dominance? Recessiveness?
4. What is meant by homozygous? Heterozygous? Partial dominance? Epistasis? Linkage? Genotype? Phenotype?
5. What is meant by lethal characters? Give examples.
6. When a black Holstein bull carrying the factor for red coat color is mated with Holstein cows carrying the same factor, what would be the genotype and phenotype ratios for the offspring?
7. Explain the meaning of outbreeding, inbreeding, close breeding, line breeding, and crossbreeding. What are the advantages and disadvantages of each?
8. Outline a sound breeding program for a herd of dairy cattle.
9. In what terms is the success of a breeding program measured?
10. What is a pedigree?
11. What information should a well-written pedigree give and not give?
12. What factors should be considered in selecting female dairy cattle to be purchased?
13. What factors should be considered in selecting a bull for use in an artificial breeding stud?
14. What is a sire index? Explain those mentioned in this chapter.
15. What is the significance of the term proved sire?
16. What is meant by the term dam-and-daughter pair?
17. What is the procedure in registering purebred dairy cattle?
18. From a breed magazine obtain 20 names which are used in naming cattle bred on particular farms.
19. List the advantages of artificial insemination of dairy cattle. List the limitations.
20. What types of organizations provide artificial breeding service?
21. How does the technician carry out his duties?
22. What are the advantages and disadvantages of using frozen semen?
23. What is the importance of production testing to artificial breeding organizations?

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CHAPTER 7

Raising Dairy Herd Replacements

The Need for Herd Replacements. The average dairy cow in the United States remains in the milking herd only a little over 4 years. This means that nearly one-fourth of the average milking herd must be replaced each year. The number of replacements which are available from an average herd to maintain it is surprisingly small. This fact is illustrated by Fig. 24, which shows how many calves are born annually to 1,000 cows, how many are lost for various reasons, and the number that are available to enter the milking herd.

Another way of expressing the situation is to use New Hampshire figures which show that the average cow could during her lifetime provide a replacement and 0.559 of a cow for an increase in cow population or for herd impovement through culling. Expressed another way, a dairyman with 20 cows would have over a period of time 2 additional replacements per yr to upbreed his herd. These data show why the average herd is not improved much over a period of years by means of culling.

The cost of raising replacements is high, both in terms of cash outlay and in decreasing the number of producing animals which can be kept with a certain amount of feed, labor, and shelter.

Reasons why animals leave the herd may be of interest because they point to possible ways of increasing productive life. Average figures from Dairy Herd Improvement Association records from 17 states are given in Table 11.

These results indicate that low production and udder trouble are by far the most serious problems faced by the dairyman in maintaining the size of his herd. Brucellosis is now a much less serious problem in most states than is indicated by these data. Breeding

1,000 Cows

900 calvings per year
Calving interval of 400 days

97 per cent single births producing 873 calves of both sexes

5 per cent dead or die at birth—a loss of 44 calves

Of 829 calves alive 48.8 per cent females—404 potentially fertile female calves

3 per cent twin births producing 54 calves of both sexes

20 per cent dead or die at birth—a loss of 11 calves

Of 43 calves alive 27.0 per cent potentially fertile females—12 potentially fertile female calves

31 calves for veal—bulls and freemartins

425 calves for veal—bulls

416 potentially fertile living female calves—10 per cent die during the first 6 mo—a loss of 42 calves

375 potentially fertile living female calves—2 per cent die 6 to 18 mo a loss of 8 calves

367 potentially fertile living female calves—8 per cent sterile at 18 mo cull loss 29 heifers

338 living bred heifers—1 per cent die 18 to 26 months—a loss of 3 heifers

335 heifers to enter the milking herd per 1,000 cows

Fig. 24. Replacement rate with good commercial management. (From New Hampshire Agricultural Experiment Station Bull. 430.)

difficulties remain a serious problem. Cows removed for dairy purposes serve as replacements in other herds.

Purchasing versus raising replacements is becoming a more debated question in many areas. With the increase in specialization, larger dairy herds, greater need for specialized equipment such as bulk tanks, higher prices of land in populated areas, and the increased cost of farm labor the raising of replacements has become a serious economic problem on many specialized dairy farms. The practices of buying replacements from less populated areas and having them raised on a contract basis by dairymen located in poorer milk market areas or by older dairymen who no longer wish to produce milk or whose farms are no longer large enough to be competitive are rapidly becoming more common. Sample contracts covering the growing of replacements are now available.

TABLE 11. RELATIVE IMPORTANCE OF VARIOUS REASONS FOR REMOVAL OF COWS FROM DAIRY HERDS

Reasons	Per Cent of Total
Low production	33.5
Dairy purposes	23.5
Udder trouble	11.5
Brucellosis	7.3
Sterility	8.2
Death	5.0
Other reasons	11.0

The raising of one's own replacements has the advantage of helping to prevent the bringing of disease on the farm. Theoretically, the dairyman also is able to follow a breeding program and can make steady improvement in his herd. Actually, available data do not support either of these arguments. Such data indicate that on the average the purchased replacement stays in the herd just as long as the raised animal and produces just as much milk. The exceptional disease carrier, however, does real damage. The purchased replacement starts to pay her purchase cost almost immediately after she enters the herd. The experienced dairyman usually is more critical of the producing ability of the animal he purchased than of the one he raised. He learns to exercise considerable skill in selecting good animals. Oftentimes there is little difference in the cost of raising and purchasing replacements. In order that replacements be available from some source, however, someone must raise them. The

raising of replacements may well become a specialized enterprise just like the production of milk. The question of whether to purchase or raise replacements should be decided on an individual farm basis with economic considerations being of greatest importance but with the disease problem being kept in mind.

Selection of Calves to be Raised. Deciding which calves to raise cannot be a serious problem with the average herd because, as pointed out previously, almost all heifer calves must be raised in order to just maintain the size of the herd. About all that can be done is to eliminate heifer calves from poorest producers and to eliminate a few calves which have particularly poor type or have been unthrifty.

When a dairyman, either through good management or good fortune, is in a position to exercise a greater degree of selection, he should try to raise only the most promising heifers. The first point to consider is the producing ability of the dam and the transmitting ability of the sire. The dairy heifer is raised to produce milk profitably. If the chances are against her developing into a cow that can do this, she should not be raised. The type of the calf also is important, not so much from the standpoint of the show ring, but from the standpoint of being able to wear well over a period of many years. Inherited factors such as pendulous udders, crooked legs, and poor capacity should be eliminated in as far as possible. Health, vigor, a good appetite, etc., are desirable qualities and should be considered in selecting calves to raise.

Feeding the Young Calf. In feeding the young calf, it should be kept in mind that the digestive tract functions initially like that of a monogastric animal, but slowly changes to a ruminant during the first several weeks of life.

The ruminant stomach is composed of 4 compartments. The relative capacity of each in order of passage of feed is given in Table 12 for both the young calf and the mature cow.

The principal difference between the ruminant and the nonruminant is the presence of the rumen, the reticulum, and the omasum. In a mature cow, these compartments may hold up to 250 qt. The rumen functions as a vat where large quantities of feed are stored until it can be broken down enough to be passed along in the digestive tract. Coarse feed is returned to the mouth by regurgitation for further chewing. Also feed is broken down by the churning and soaking action in the rumen. The most important action, however, is brought

about by the fermentation processes which take place in the rumen. These processes are brought about by large numbers of different types of organisms (bacteria, protozoa, and yeasts) and result in the following chemical changes:

1. Protein and other nitrogenous compounds are broken down into ammonia. Then the ammonia from the feed and from other nonprotein compounds in the feed, such as urea, are synthesized into cell protein by the microorganisms. These microorganisms are then digested further on in the digestive tract in the usual manner and provide the animal with all of the essential amino acids.

2. Cellulose and other complex carbohydrates, as well as the sugars such as those in molasses, are broken down into volatile fatty acids (V.F.A.) which are absorbed directly from the rumen and the omasum. The principal acids formed are propionic, acetic, and butyric. These provide an appreciable part of the energy needed by the animal.

TABLE 12. RELATIVE CAPACITY OF STOMACH COMPARTMENTS OF CALF AND COW

Compartments	Calf	Cow
	Per Cent	
Rumen or paunch	30	80
Reticulum or honeycomb		5
Omasum or manyplies	70	8
Abomasum or true stomach		7

3. B-complex vitamins are synthesized in the rumen and need not be included in the diet after normal rumen activity has developed.

For these reasons, the ruminant can make economical use of coarse feeds such as forages which would be of little use to other types of animals.

Feeding the young calf is an important job. The calf should receive colostrum, the first milk secreted after parturition, for at least 2 days after birth. It can nurse the dam or be fed the fresh, warm colostrum at the rate of 4 per cent of the body weight of the calf twice per day. Colostrum is important because it provides antibodies which give the calf resistance to disease, has laxative properties which clean the meconium or digestive residue from the newborn calf, and is high in nutritional value, especially carotene, vitamin A, vitamin D, protein, and minerals. When the calf cannot be

allowed to receive the fresh colostrum from the dam, it should be fed warmed colostrum which has been preserved in the freezer or regular milk plus supplementary vitamins A and D. Castor oil can be used as a laxative in such cases if needed.

A few rules which are important in feeding calves are:

1. Feed warm milk at a uniform temperature.
2. Feed from clean pails.
3. Feed regularly.
4. Do not overfeed.
5. Make changes in feed gradually.
6. Weigh or measure milk for calves.

There are several methods which are followed in feeding calves during the first several weeks of life. One method has no particular advantage over any other. The situation in the area or on the particular farm should be the deciding factor.

The whole milk method is to feed whole milk at the rate of 8 to 10 per cent of the body weight per day until the calf is 3 to 6 months of age. A simple concentrate mixture composed of home-grown grains can be used successfully with this method. This method is not used extensively at the present time.

The limited whole milk–dry calf starter method has been used very commonly in market milk areas. Whole milk is fed 6 to 8 weeks with the total amount being limited to 250 to 300 lb. A dry calf starter, which usually contains some milk product and approximately 20 per cent crude protein, is fed ad libitum until a maximum of 3 to 4 lb per day is consumed. This is fed until the calf is approximately 3 to 5 months of age. Any additional concentrate fed is a regular dairy mixture. The type of feeding schedule generally recommended under this plan is given in Table 13.

The milk replacer-dry calf starter method is essentially the same as the previous method except that a milk replacer, an example of which is given in Appendix D, is fed in the place of whole milk. The change from whole milk to milk replacer takes place by the end of the first week. The replacer usually is reconstituted with warm water at the rate of 1 lb of replacer to 9 lb of water. A 25-lb pail of replacer is considered to be enough for one calf.

Skim milk, either fresh or reconstituted, can be used to replace whole milk or milk replacer in the feeding of calves. Skim milk powder is reconstituted at the rate of 1 lb of powder to 9 lb of water. When skim milk is fed vitamins A and D should be included in the ration, because skim milk is essentially devoid of fat and thus

the essential fat soluble vitamins. In those instances in which large quantities of skim milk are available, it can be fed to calves at the daily rate of 8 to 10 per cent of the body weight until they are 6 months to 1 year of age. Under such a feeding program a simple grain mixture is adequate.

TABLE 13. CALF FEEDING SCHEDULE
(Daily Basis)

Age of Calf	Whole Milk, pounds	Dry Calf Starter, pounds	Fitting Ration, pounds	Hay
Brown Swiss and Holstein Calves				
1–3 days	With dam			
4–7 days	7			
2nd week	9	1/8		
3rd week	10	1/4		Free access
4th week	8	3/4		Free access
5th week	6	1 1/4		Free access
6th week	4	1 3/4		Free access
7th week	2	2 1/4		Free access
8th week	Weaned	2 3/4		Free access
9th week		3 1/4		Free access
10th–14th week		3–4		Free access
15th–16th week		4–0	0–4	Free access
17th–24th week			4–5	Free access
Ayrshire, Guernsey, and Jersey Calves				
1–3 days	With dam			
4–7 days	5			
2nd week	6	1/8		
3rd week	7	1/4		Free access
4th week	7	1/2		Free access
5th week	5	1		Free access
6th week	4	1 1/2		Free access
7th week	3	1 1/2		Free access
8th week	2	2		Free access
9th week	Weaned	2 1/2		Free access
10th–14th week		3–3 1/2		Free access
15th–16th week		3 1/2–0	0–3 1/2	Free access
17th–24th week			3 1/2–4	Free access

Whey, buttermilk, and semisolid buttermilk also can be used if proper supplements are made and precautions taken.

The concentrate mixture generally should be fed as soon as the calf will eat it. The amount eaten usually will increase as the amount of milk or replacer is reduced. Calves generally learn to eat con-

centrate readily if it is placed in a small box in the calf pen, but the process can be hastened by rubbing the concentrate mixture on the calf's nose immediately after it finishes drinking milk.

Early-cut mixed hay should be offered to calves at an early age. Most animals will begin eating it between 10 days and 3 weeks of age, and they should continue to have all they will eat.

When heifers are 6 months of age they should receive 3 to 5 lb of dairy concentrate daily in addition to all the forage they will eat. Good hay-crop silage can replace much of the hay but not all of it. Pasture can be used, but one must make sure that too much dependence is not placed on it as a source of nutrients. In most cases better results are obtained if animals are not turned on pasture until they are 10 to 12 months of age.

Housing and Management of the Young Calf. The care of the young calf also is very important. An excellent set of recommendations on calf management was prepared in 1951 by the Nutrition Council of the American Feed Manufacturers' Association. The complete list, including feeding, is given below. These recommendations also can serve as a guide in the planning and construction of facilities for housing calves.

HOUSING CALVES. (1) Dairy calves should be raised separately—one calf to a pen for at least 1 week after milk or milk substitute is discontinued. (2) Calves may be raised in groups beginning one week after milk or milk substitute is discontinued. (3) Ten calves should be the maximum number raised in one group, provided that floor and feeding space is adequate and calves are liberally fed. (4) The maximum age difference between calves in any group should not exceed 2 months. It is important to see that all calves are actually eating their fair share.

SPACE NEEDS. (5) Minimum pen size for individual calves is 24 sq ft. (6) Minimum pen size for calves in groups with no outside run is 30 sq ft per calf.

WATERING DEVICES. (7) Automatic drinking cups are preferred for calf waterers. Where pails are used for watering, they should be kept clean and well filled with fresh water. (8) Automatic drinking cups are preferred for calves housed in pen groups. Where watering tanks are used for calves in outside runs, the water should be fresh and the tanks kept in sanitary condition. (9) Top of drinking cups for calves should be 20 in from the floor. (10) Watering equipment for calves in individual pens should be located at a front corner of the pen away from the feed. (11) Watering equipment

for calves in groups should be at front corners of the pen or an outside tank. (12) Provide 2 automatic drinking cups when more than 5 calves are housed per pen.

FEEDBOXES. (13) Calf-ration feedbox for the individual pens should be $8 \times 10 \times 6$ in. deep. It is desirable to make boxes removable for cleaning. (14) When calves are raised in groups, calf ration feedboxes should be 10×6 in. deep, allowing 2 ft per calf. Two troughs per pen are preferred.

MANAGEMENT RECOMMENDATIONS. (15) Top of calf-ration feedboxes should be 20 in. from floor. (16) Locate calf-ration feedboxes at front of individual pens away from waterer. (17) For calves fed in groups, locate feedboxes where convenient but away from waterers.

PEN CONSTRUCTION. (18) Solid partitions between individual calf pens will reduce chilling drafts.

TEMPERATURE. (19) Desirable pen temperature range for raising young calves is 50 to 75° F. Keep temperature as uniform as practicable. Sudden variations in temperature are particularly dangerous. Dryness in pen is important because dampness intensifies cold.

FEEDING. (20) There is no minimum time to leave the vigorous newborn calf with the cow. It is very important that the calf gets colostrum the first 3 days either by nursing or drinking. (21) Young calves may be taught to drink from a pail or a nipple-feeding device. It is important that pails or other calf-feeding equipment be kept scrupulously clean at all times to avoid digestive disturbance. (22) Calves may be turned out to pasture as soon as practicable after 4 months of age. They should continue to get their usual feed and have access to salt, water, and shade. (23) High-quality hay should be fed to calves from the start. (24) Ensilage may be fed after calves are 6 months old. (25) A safe age at which whole milk or milk substitute may be replaced entirely by a suitable calf starter, grain mixture, and roughage will depend on the kind of start the calf had and its vigor. Usually 6 weeks can be considered a safe age for this change, though healthy vigorous calves may be changed as much as 2 weeks earlier with good results.

Growth of Calves. On an actual weight basis, the growth rate of the calf increases from conception to puberty and then gradually decreases to maturity. On a percentage basis, however, the rate decreases from conception to maturity. This decrease can be understood when one considers that shortly after conception the number of cells in the fetus doubles several times a day.

The growth period is divided into prenatal and postnatal periods.

Also, the period from birth to puberty is known as the self-accelerating period and that from puberty to maturity as the self-inhibiting period. Senility is that period of advanced age when there is a shrinkage.

Birth weights of heifer calves of the various breeds are indicated by the first values in Table 14. Bull calves tend to be heavier than heifer calves, the difference for the various breeds being as follows: Ayrshire 8 lb, Guernsey 6 lb, Holstein 5 lb, and Jersey 7 lb. The larger breeds generally produce larger calves than the smaller breeds. Cows produce larger calves from the third to sixth calving than when younger or older. Except in extreme conditions, the nutritional state of the cow has little if any affect on the size of the calf at birth. Nutritional requirements of the fetus generally are met at the expense of the dam.

Normal growth tables have been developed for dairy cattle by several different agricultural experiment stations. These tables give values for both body weight and height at withers. This latter value is used as a measure of skeletal size. If a person considered only body weight, he would get an erroneous picture in some cases, because an animal might be fairly normal in skeletal size but be in a rather thin condition. The breeds must be treated separately because they vary markedly in growth rate and age at maturity. Bull calves develop more rapidly than heifers so the sexes must be treated separately. The normal growth rates for Ayrshire, Guernsey, Holstein, and Jersey heifers are given in Table 14.

In cases where scales for weighing animals are not available, Table 15 can be used for estimating body weight from the heart girth. Because the relationship between body weight and heart girth has been worked out for large numbers of animals, the average estimated weight for several animals is very close to the average actual weight. On an individual animal basis, however, there will be some error due to variation in conformation, fill, body condition, etc. Tape measures which can be read in lb are available for estimating the weight of cattle.

Feeding and Care of Yearling Heifers. The yearling heifer frequently is the most neglected dairy animal on the farm. Because she is old enough to get by without much attention and is not yet producing milk, she often is not given the attention she deserves.

HOUSING. Housing is not a serious problem. An open shed which will give the heifer a dry place free from drafts is ideal. Temperature is not an important consideration. Many times the well-fed heifer will lie out in the snow instead of in the shed. The shed

TABLE 14. NORMAL WEIGHT AND HEIGHT OF DAIRY HEIFERS

	Ayrshire		Holstein		Jersey		Guernsey	
Age, months	Weight, pounds	Height at Withers, inches	Weight, pounds	Height at Withers, inches	Weight, pounds	Height at Withers, inches	Weight, pounds	Height at Withers, inches
Birth	72	27.6	90	29.1	53	25.7	65	26.6
1	89	28.6	112	30.6	67	27.0	77	28.2
2	119	30.2	148	32.3	90	28.9	102	29.8
3	158	31.9	193	34.3	121	30.6	133	31.6
4	198	34.0	243	36.2	158	32.6	173	33.5
5	245	35.5	297	37.7	199	34.5	216	35.3
6	293	37.2	355	39.7	243	36.2	260	36.9
7	344	38.5	410	41.1	286	37.7	305	38.4
8	389	39.9	462	42.3	324	39.0	350	39.9
9	433	40.9	509	43.5	360	40.1	389	40.9
10	469	41.7	552	44.4	393	40.9	427	41.7
11	502	42.5	593	45.3	420	41.7	459	42.6
12	538	43.2	632	46.0	450	42.2	490	43.3
13	577	44.0	671	46.7	479	42.8	524	43.9
14	611	44.8	705	47.3	507	43.3	556	44.6
15	638	45.1	746	47.9	530	43.9	584	45.0
16	669	45.7	782	48.5	558	44.4	605	45.3
17	697	46.2	809	48.9	580	44.7	634	45.9
18	725	46.5	845	49.3	601	45.2	663	46.4
19	758	46.8	878	49.8	662	45.5	686	46.7
20	793	47.4	912	50.2	642	45.9	712	47.0
21	818	47.6	952	50.6	665	46.2	737	47.3
22	844	47.8	986	51.0	684	46.4	763	47.7
23	871	48.1	1024	51.3	708	46.7	788	47.9
24	902	48.3	1069	51.7	733	46.9	818	48.0
30	945	48.3	1120	52.5	824	47.9	880	49.3
36	968	48.7	1165	53.0	855	48.2	901	49.9
48	1035	50.2	1232	53.3	897	48.5	990	50.4
60	1080	50.4	1330	53.6	937	49.0	1055	50.6
96	1143	49.2	1365	53.2	909	47.7	1070	49.6

Missouri Agricultural Experiment Station Bull. 336.

should be available, however, to take care of the heifer during cold rains, high winds, and other times when shelter is needed.

WATER. Water should be available at all times if possible. It is particularly important during hot weather. Electrically heated water bowls and tank water heaters are available for freezing weather.

When heifers cannot be provided free access to water, they should be allowed to drink twice per day.

PASTURE. Pasture can provide all of the nutrient needs of heifers 11 or 12 months of age to 2 months before freshening, if it is of reasonably good quality. Because they do not require nutrients for milk production, heifers do not need as good pasture as milking cows. One can tell whether heifers have adequate pasture by the way they grow, their body condition, the condition of the pasture, and if they appear restless and want additional feed.

TABLE 15. ESTIMATING THE WEIGHT OF DAIRY COWS AND YOUNG STOCK FROM HEART GIRTH MEASUREMENTS

Heart Girth, inches	Weight, pounds	Heart Girth, inches	Weight, pounds	Heart Girth, inches	Weight, pounds	Heart Girth, inches	Weight, pounds
26	80	41	224	56	526	71	1027
27	84	42	240	57	552	72	1069
28	89	43	257	58	579	73	1111
29	96	44	275	59	607	74	1153
30	101	45	294	60	637	75	1197
31	108	46	314	61	668	76	1241
32	118	47	334	62	700	77	1285
33	128	48	354	63	732	78	1331
34	138	49	374	64	766	79	1377
35	148	50	394	65	800	80	1423
36	158	51	414	66	835	81	1469
37	168	52	434	67	871	82	1515
38	180	53	456	68	908	83	1561
39	192	54	478	69	947	84	1607
40	208	55	501	70	987	85	1653

U.S. Department of Agriculture.

When pasture is inadequate, it can be supplemented by feeding hay-crop or corn silage, hay, or 2 to 5 lb of concentrate per day. The amount of supplemental feed would depend on the need. Heifers on pasture should have shade and free access to salt.

BARN FEEDING. Barn feeding of heifers is not a difficult problem. They will make satisfactory gains on reasonably good hay alone, hay and corn silage, and on hay-crop silage and limited hay. Good hay-crop silage alone will give reasonably good results, but the addition of ¾ lb of hay per 100 lb body weight will improve nutrient intake

considerably. Forage generally is fed to heifers to the limit of what they will clean up. Concentrates should be fed to the extent needed, but more economical growth generally can be obtained on liberal feeding of good forage. Free access to salt should be provided.

Because gains generally can be obtained much more economically on pasture than on barn feeding, dairymen sometimes carry heifers that will not freshen before fall through the previous winter on a feed intake which will keep them healthy and permit only a minimum of growth. When these heifers are turned out on pasture in the spring, they make very rapid gains and will be of normal size by fall if the pasture is adequate. Similar heifers, which have been fed

TABLE 16. RECOMMENDED MINIMUM BODY WEIGHTS, HEART GIRTHS AND AGES FOR BREEDING HEIFERS

Breed	Body Weight, pounds	Heart Girth, inches	Age, months
Ayrshire	650	61	16
Brown Swiss	750	64	16
Guernsey	550	57	14
Holstein	750	64	14
Jersey	500	55	13

so as to make maximum winter gains, will make only moderate gains on pasture and end up in the fall at about the same weight as the animals given a minimum of winter feed.

Age to Breed. Dairymen are gradually changing to the practice of breeding heifers on the basis of body size instead of age. This is controlled to some extent by nature, because heifers usually do not start coming into heat until they are about a certain size for each breed. The minimum weights and ages for breeding heifers are given in Table 16. Heifers bred at these weights or ages must be fed liberally for satisfactory results.

By liberal feeding and breeding according to body weight, it is possible to get replacements into the milking herd sooner. This may increase the cost of raising replacements, but it reduces the time during which animals are being carried without any return and also reduces the number of such animals which are being carried.

The gestation period for cows of all breeds will normally range from 265 to 295 days. That there is a breed difference is shown by Table 17. First calf heifers generally have a gestation of about 2

days less than older cows of the same breed. Male calves generally are carried about one day longer than heifers.

Feed and Care at Calving Time. During the last 2 or 3 months of pregnancy, the heifer should be given 3 to 8 lb of concentrates per day. The amount will depend on the condition of the heifer and the quality of the forage. Because the level of production of the heifer will depend to a considerable extent on her condition at calving, she should be fed so as to be in good flesh when she freshens. Excessive condition, however, is undesirable.

TABLE 17. GESTATION PERIOD FOR VARIOUS BREEDS

Breed	Average Length, days
Ayrshire	278
Brown Swiss	288
Guernsey	283
Holstein	279
Jersey	278

Whenever possible, the heifer should be allowed to go into the barn with the milking herd a few weeks before she freshens. It also is a good practice to give her special attention, such as grooming and handling of her udder. When she starts to produce she is then much more at ease and will produce better. The heifer should be allowed to freshen in a clean box stall or better still in a clean lot near the barn during warm weather. She should be watched as much as possible without her being conscious of it. It will thus be possible to provide assistance during parturition if it is needed and also see that the calf is cleaned off and given milk in case the heifer will not own it. Because a heifer is very nervous at this time, she should be kept as quiet as possible.

QUESTIONS

1. Why is there so little opportunity for culling in the average dairy herd?
2. What is the principal reason for culling in the average dairy herd?
3. List the advantages and disadvantages of purchasing and raising dairy herd replacements.

4. What factors should be considered in selecting dairy heifers to be raised?
5. What are the names of the stomach compartments in the ruminant and what is their relative capacity in the young calf and in the mature cow?
6. What changes take place in the feed in the rumen as a result of mechanical action?
7. What chemical changes take place in the feed in the rumen?
8. What is the recommended rate for feeding milk to the young calf?
9. List six rules for feeding young calves.
10. What common methods for feeding calves are now in use?
11. What is the usual rate for reconstituting skim milk from powder?
12. What kind of hay is desired for feeding calves? At what rate should it be fed?
13. What do young calves require in the way of shelter?
14. Define the four different growth periods.
15. How does the growth rate of the calf change with age?
16. How is the birth weight of calves affected by the following: breed, sex, age of dam, and nutrition of dam?
17. Outline a satisfactory feeding program for yearling heifers.
18. What do yearling heifers require in the way of housing?
19. What are the minimum weights and ages for breeding heifers of the various breeds?
20. What is the average gestation period for each breed?

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CHAPTER 8

Feeding Dairy Cattle

Uses for Feed. Inadequate feed probably limits the production of more dairy cows than any other factor. Care and management probably rank next in importance. Inheritance is rarely the limiting factor that it generally is thought to be. Dairy cattle use feed for the following purposes:

1. Maintenance
2. Growth
3. Milk production
4. Pregnancy

MAINTENANCE. Maintenance is the sum of those needs for food for keeping the body functioning properly, replacing worn-out tissues, maintaining body temperature, and supplying energy for muscular activity. When the maintenance requirements of a nonpregnant, nonlactating animal are met exactly, the body stores of protein, fat, and mineral matter are held constant. Approximately one-half of the feed consumed by a lactating cow is used for this purpose. The maintenance requirements of a cow are roughly proportional to body size. Cows are individuals, however, and may vary some from the published values.

GROWTH. Growth requirements, which are needs for increase in body size, can be met only after maintenance needs have been satisfied. Growth requirements vary with age, breed, sex, and stage of development. In relation to body weight, young animals have much higher requirements than mature animals for protein, energy,

vitamins, and minerals. Also young animals suffer earlier and more severely from certain nutritional deficiencies.

MILK PRODUCTION. These requirements depend on both the amount of milk that a cow is producing and the butterfat test. A cow producing 50 lb of milk daily requires twice as much protein and energy above her maintenance requirements as the cow producing 25 lb containing the same butterfat test. More nutrients are required to produce a pound of 5 per cent milk than 1 lb of 3.5 per cent milk. If the nutritive requirements for milk production are not met, the cow will draw on her body reserves. When these reserves have been used up, production will drop to the amount that can be produced from the nutrients that she receives in excess of maintenance.

PREGNANCY. Pregnancy requirements are relatively low, but they should not be ignored. Pregnant animals should be fed adequate amounts of all nutrients. During the last two months before parturition, the recommended energy allowance for the pregnant heifer is 50 to 60 per cent higher than for a nonpregnant heifer of the same size.

Feed Nutrients. The nutrients of feeds are classified into several groups, namely, water, carbohydrates, protein, fat, minerals, and vitamins.

WATER. Water plays an extremely important function. It is a constituent of all body tissues and fluids. Large amounts of water are needed for the digestive process. Also, water helps to carry nutrients to the various parts of the body, to control the temperature of the body, and to remove waste products. The body of the mature cow contains approximately 70 per cent water and milk contains about 87 per cent. A cow needs approximately 4 to 5 lb of water for each lb of milk produced.

CARBOHYDRATES. In feeds carbohydrates generally are divided into two groups. The nitrogen-free extract is composed chiefly of starches and sugars. The members of this group are digested readily and have a high feeding value. The other group of carbohydrates is commonly designated as fiber. The members of this group generally have a much lower feeding value. Feeds high in fiber are usually lower in digestible nutrients. Carbohydrates are used primarily for energy, but amounts not needed for this purpose are converted into body fat.

PROTEIN. Protein is that part of the feed which contains nitrogen. Protein is essential for growth, tissue repair, and milk production. Because milk is rich in protein, high-producing cows need relatively

large amounts of this nutrient. Protein has been considered to be a stimulant for milk production, but this appears not to be the case.

FAT. Fat is considered to be that portion of a feed which can be extracted by means of ether. Although the cow needs to get certain unsaturated fatty acids from the feed, the requirement is met by most rations. The principal value of fat in the ration is that it is a more concentrated source of energy than carbohydrates or protein.

MINERALS. Minerals are needed for skeletal growth and normal body functioning. Those elements which are needed in relatively large amounts, such as calcium, phosphorus, magnesium, sodium, chlorine, etc., are called the macro elements or major elements. Those which are needed in relatively small quantities, such as cobalt, iron, copper, manganese, and zinc are known as the micro elements, minor elements, or trace minerals. The essential elements must be provided not only in adequate amounts but also in proper balance if optimum results are to be obtained.

Common salt is needed to maintain osmotic pressure, to provide the chlorine in the hydrochloric acid in the gastric juice, and for other purposes. It is more likely to be deficient than any other mineral. Deficiency symptoms are a craving for salt, a lack of appetite, and a rough hair coat. Milking cows lose weight and decline in milk production. The daily salt requirement of cattle is 0.75 oz per 1,000 lb of body weight, plus 0.3 oz for each 10 lb of milk produced. Salt generally is included in concentrate mixtures at the rate of 1 per cent. In addition it should be provided free access in loose or block form.

Calcium is required for the formation of bone and other tissues, milk synthesis, and various vital functions. Although its lack can result in fragile bones, most rations contain adequate calcium. Requirements decrease with age as shown in Appendix C. The more commonly used supplements are calcium carbonate, dicalcium phosphate, steamed bone meal, and defluorinated rock phosphate.

Phosphorus in addition to its role in bone formation has important functions in many metabolic processes. A deficiency of this element is much more likely to be a problem than calcium deficiency. Symptoms are depraved appetite, stiffness of joints, fragile bones, and a low inorganic blood phosphorus level. The deficiency has been encountered in areas where the soil is deficient in phosphorus and elsewhere when inadequate phosphorus has been included in the ration. Commonly used phosphorus supplements include steamed bone meal, dicalcium phosphate, and defluorinated rock phosphate. Require-

ments of this element as shown in Appendix C also decrease with age.

Magnesium also is needed for bone formation and for other vital functions. A deficiency may occur in calves maintained on a milk diet for a period of many weeks. It is characterized by convulsions. Cattle fed normal rations are not known to suffer from the deficiency. The magnesium requirement of calves has been reported to be 0.07 per cent of the ration on a dry basis. A condition known as "grass tetany" sometimes occurs in cows just after they are turned on lush pasture. This condition is characterized by a low-blood magnesium content, but the magnesium intake usually is in the normal range.

Iodine is needed by the thyroid gland in the production of the hormone thyroxine. A deficiency sometimes occurs in areas where this element is contained in inadequate amounts in the soil. The principal effect of the deficiency is the birth of calves with enlarged thyroid glands or goiter. These calves generally are weak or dead at birth. The iodine requirement of cattle has been reported to be about 90 parts per billion in the ration. The deficiency can be prevented by the feeding of iodized salt to the dam during gestation.

Iron is needed for the production of hemoglobin. A deficiency results in anemia. This condition is relatively rare. It has been observed in young calves fed almost entirely on milk and in older animals maintained in a few iron deficient areas in the world.

Cobalt deficiency has been found in several areas in the United States. It is characterized by a loss of appetite, depraved appetite, emaciation, and weakness. This element is needed by the rumen flora in order to synthesize the vitamin B_{12} needed by the animal. The cobalt requirement of cattle is 0.07 to 0.10 parts per million in the ration. The element can be provided by feeding salt or mineral mixtures containing cobalt or cobalt supplemented concentrates. It is usually added to the latter at a rate of 2 g of cobalt sulfate or equivalent of some other cobalt salt per ton of feed.

Copper is needed for the proper use of iron in hemoglobin formation, bone growth, and other uses. Copper deficiency has been reported in a few areas in the United States. This condition is characterized by severe diarrhea, loss of weight, abnormal appetite, rough, coarse, bleached hair coat, and anemia. Fragile bones also are common. The effects of excessive molybdenum intake can be corrected by the feeding of increased amounts of copper. The copper requirement of cattle is reported to be approximately 4 to 5 parts per million in the ration.

For more detailed information on the function and requirements of

the various minerals in the ration of dairy cattle, it is recommended that the *National Academy of Sciences–National Research Council Publication 464*, "Nutrient Requirements of Dairy Cattle" (1956 revision) be consulted. Also note the tables in Appendix C.

VITAMINS. Vitamins also are needed by dairy cattle. The problem of vitamin supplementation is not nearly as great with this species as with many other farm animals. Detailed information on this subject is provided in *Publication 464* of the National Academy of Sciences–National Research Council.

Vitamin A, a colorless, fat-soluble material is made by the animal body from carotene, a yellow pigment found in leafy plant materials. In the young calf common deficiency symptoms are watery eyes, cold in the head, and diarrhea. Symptoms found in older animals are night blindness, muscular incoordination, convulsive seizures, blindness, and unthriftiness. In pregnant animals the deficiency may result in abortion or birth at full term of dead, weak, or blind calves.

Immature pasture, hay-crop silage, and green, leafy hay are excellent sources of vitamin A activity in the form of carotene. Common supplements are crystalline vitamin A, alfalfa leaf meal, and fish liver oils. One of these supplements usually is included in milk replacers and dry calf starters and frequently in concentrates intended for dry cows and for feeding with poor quality hay.

Vitamin D is a fat-soluble material needed for normal bone development. This vitamin is produced in both plant and animal tissue, through the effect of ultraviolet irradiation on certain sterols. A form of the vitamin known as D_2 is more effective for four-footed animals, whereas that known as D_3 is more effective for poultry. D_3 is used in cattle feed in the place of D_2, however, when the price is low enough to more than offset the increased amount needed.

A lack of vitamin D can occur in calves maintained in dark places and fed very little or no sun-cured forage. The deficiency is very rare in mature cattle. Rickets is the term commonly given to vitamin D deficiency in calves. This condition is characterized by the forelegs bending forward or sidewise or both, the knee and hock joints becoming swollen and stiff, and the back becoming humped. Advanced cases are characterized by stiffness of gait, dragging of hind legs, irritability, tetany, labored and fast breathing, loss of appetite, and poor growth. Liberal feeding of sun-cured hay usually will provide adequate vitamin D for older calves and mature animals. Supplemental vitamin D normally is included in the ration of the young calf. Common vitamin D supplements include D-activated plant sterol, irradiated yeast, and fish liver oils.

B complex vitamins are needed by the bovine body but they need not be supplied by the ration except with the young calf. These water-soluble vitamins, which include thiamin, riboflavin, biotin, pantothenic acid, nicotinic acid, and vitamin B_{12}, are synthesized by the flora of the rumen in quantities which meet the needs of the ruminating animal. Milk and milk replacers generally supply the needs of the young calf.

Vitamin C apparently is synthesized in sufficient quantities in the tissues of cattle to take care of their needs under usual conditions. Actually, vitamin C included in the ration is destroyed to a considerable extent in the rumen and can thus be ignored in dairy cattle feeding under usual conditions.

Vitamin E has been proven to be essential for cattle. A deficiency affects skeletal muscles in calves and heart muscles in mature animals. A deficiency of this fat-soluble vitamin in cattle does not have any appreciable effect on reproduction, as has been so commonly believed. Under most conditions the ration of cattle will contain adequate amounts of vitamin E.

Vitamin K is involved in the clotting of blood. It is, therefore, referred to as the antihemorrhagic vitamin. It is formed by bacterial action in the rumen and intestine. Green plants and dried forages are excellent sources of it. A vitamin K deficiency is not a problem in the feeding of cattle.

Characteristics of the Ration. There are several characteristics of a feed or ration that affect its consumption and utilization. Among these are palatability, variety, bulk, and laxativeness. Both forages and concentrates should be as palatable as possible. If the forage is not palatable, cows will eat less of it and it will be necessary to feed larger quantities of concentrates. Corn stover, late-cut hay, and spoiled silage are less palatable than corn silage, early-cut hay, and well preserved hay-crop silage of good quality.

It is usually easy to provide a palatable concentrate mixture for dairy cows. They like most common grain and by-product concentrates. Such feeds as ground corn, ground or crimped oats, wheat bran, linseed oil meal, and molasses improve the palatability of a concentrate mixture.

Greater variety frequently improves a ration, both from the standpoint of nutritional quality and the amount that the animals will consume. A good mixed grass-legume forage offered in the form of hay, silage, or pasture often is more palatable than a single type of forage. A combination of hay and silage frequently results in greater dry

matter consumption than either one fed as the sole forage. A combination of several concentrates is often more palatable than a simple mixture.

If cows eat normal amounts of forage, bulkiness of the concentrate mixture is not a problem. Bulkiness of the concentrate mixture is desirable, however, if the ration contains a relatively large amount of concentrates and a limited amount of forage.

Slightly laxative feeds are desirable. Feeds such as wheat bran, linseed oil meal, beet pulp, and molasses counteract the constipating nature of mature hay, corn stover, and straw. Liberal amounts of legume hay or good silage will produce the desired laxative effect in a balanced ration.

Nutritive Evaluation of Feeds. The usual chemical analysis of a feedstuff is called the proximate analysis. From this analysis we get crude protein which is the nitrogen content $\times$ 6.25 (Protein averages 16 per cent nitrogen), the ether extract or fat, crude fiber, ash, moisture, and nitrogen-free extract. This last ingredient is determined by adding the percentages of the other ingredients and subtracting the sum from 100. The proximate analysis tells us what is in the feed but relatively little as to what the animal will get out of it.

In order to evaluate a feed on the basis of what an animal can get out of it, we have developed methods which consider the value of the feed to the animal. These will be discussed.

DIGESTION COEFFICIENT. This is that percentage of a particular ingredient which is calculated to be absorbed by the animal. It is calculated by the following formula:

$$\frac{\text{Wt of ingredient eaten} - \text{wt of undigested ingredient in feces}}{\text{Wt of ingredient eaten}} \times 100$$
$$= \text{Digestion coefficient of ingredient}$$

DIGESTIBLE PROTEIN. Digestible protein is that amount of protein in a feed which is absorbed from the digestive tract expressed as a per cent of the total feed. It is calculated by the following formula:

$$\text{Per cent crude protein in the feed} \times \text{digestion coefficient for protein in the feed} = \text{Per cent digestible crude protein in the feed}$$

This is the common basis for evaluating the protein in a feed. It appears to have no serious defects, particularly as far as ruminants are concerned.

TOTAL DIGESTIBLE NUTRIENTS. This is the most commonly used method for evaluating the energy content of a feed. It is determined by adding the following:

Crude protein content $\times$ digestion coefficient of protein =
Crude fiber content $\times$ digestion coefficient of crude fiber =
Nitrogen-free extract content
$\times$ digestion coefficient of nitrogen-free extract =
Ether extract content
$\times$ digestion coefficient of ether extract $\times$ 2.25 = ______
Total digestible nutrient content =

In spite of its common usage the T.D.N. determination is not a simple or accurate one. It requires many chemical analyses and it tells nothing about how the animal uses the nutrients after they are absorbed. Also, it ignores the approximately 10 per cent of the consumed energy which is converted to methane in the rumen and wasted. The factor of 2.25 is used to put the energy content of fat on a basis comparable to that of protein or carbohydrate.

GROSS ENERGY. This is the total energy content of a feed as determined by burning it in a bomb calorimeter. Values are expressed in the usual heat units. A *calorie* (small calorie) is the heat which is required to raise the temperature of 1 ml of water 1° C. A *Calorie* (large calorie) equals 1,000 cal or that amount of heat which is required to raise the temperature of 1 liter of water 1° C. A therm is 1,000 Calories and was used by Armsby to put heat units as used in the nutrition of large animals in convenient terms. Gross energy is easily and accurately determined on feeds, urine, feces, and milk. It is expressed in terms of calories or therms per unit of feed.

METABOLIZABLE ENERGY. Metabolizable energy represents that portion of the gross energy which is available for the metabolic activities of the body. It is determined as follows:

$$\frac{\text{Gross energy eaten} - \begin{pmatrix}\text{gross energy of urine} + \text{gross energy of feces}\\ + \text{ gross energy in combustible gases } (CH_4)\end{pmatrix}}{\text{Units of feed eaten}}$$
$$= \text{Metabolizable energy per unit of feed}$$

Metabolizable energy from a theoretical standpoint is a very good measure of energy value. It requires that the energy loss in the urine and methane also be determined. It ignores the heat increment or work of digestion. This measurement is used very little at the present time.

NET ENERGY. Net energy is a measure of that part of the gross energy which is truly available for maintenance and productive purposes such as growth and milk production. The formula for its calculation is as follows:

$$\frac{\text{Gross energy eaten} - \begin{pmatrix}\text{gross energy in urine} + \text{gross energy in feces} \\ + \text{gross energy of methane} + \text{heat increment}\end{pmatrix}}{\text{Units of feed eaten}} = \text{Net energy per unit of feed}$$

Theoretically net energy is the best known measure of the energy value of a feed. Actually it is not particularly satisfactory as currently used. It requires the use of a respiration chamber in the indirect measurement of heat production. The *heat increment* must be determined by measuring heat production on two levels of nutrient intake or on feed and on fast.

One formula for this is as follows:

$$\frac{\text{Heat production on } 2X \text{ maintenance} - \text{heat production on maintenance}}{\text{Units difference in feed intake}} = \text{Heat increment per unit of feed}$$

Also net energy varies with the use to which the nutrients are being put. In other words, one obtains different values for maintenance, growth, and milk production. Because of the variability in net energy values and the fact that few agricultural experiment stations are equipped to measure it, it is rarely used except on an estimated basis. With proper standardization of methods for measuring it, however, it is believed by many nutritionists that net energy can become the most reliable measure of the energy value of livestock feeds. It should be particularly useful in putting the energy evaluation of all types of feeds, particularly high-quality concentrates and low-quality forages, on a common basis.

DIGESTIBLE ENERGY. Digestible energy is gaining in general usage among workers in animal nutrition. Theoretically, one should not refer to digestibility of energy. Because this terminology is coming into general usage, however, it will have to be accepted anyway. It is calculated as follows:

$$\text{Gross energy in unit feed} \times \text{digestion coefficient for energy} = \text{Digestible energy per unit feed}$$

In this calculation the digestion coefficient is determined in the usual manner. This method of evaluating feed is comparable to

T.D.N. in what it represents, but it is very simple to determine because the only determinations required are energy measurements on the feed and on the feces. This evaluation can be carried out accurately, quickly, and cheaply. It is hard to break tradition, however, in changing from T.D.N. to digestible energy. It would require that large numbers of T.D.N. values be converted to digestible energy equivalents. The formula for this is as follows:

$$\text{Lb T.D.N.} \times 2 = \text{Therms digestible energy}$$

This calculation is based on the fact that 1 lb of T.D.N. contains 2,000 Calories of digestible energy.

DIGESTIBLE DRY MATTER. Digestible dry matter is sometimes used in comparing similar feeds on an experimental basis, but rarely in practical livestock feeding. It is calculated as follows:

$$\text{Dry matter per unit feed} \times \text{digestion coefficient for dry matter} = \text{Digestible dry matter per unit feed}$$

Characteristics of Common Feeds. CONCENTRATES. The term concentrate is applied to that group of feeds which are relatively high in total digestible nutrients and low in crude fiber. Feeds falling in this group are the cereal grains and their by-products, the oil meals, feeds of animal origin, beet and citrus pulps, and molasses. The term concentrate is used because the nutrients are in a concentrated form as compared to those in the forage crops.

Corn heads the list for palatability and total digestible nutrient content. It is used in some form in nearly all commercially mixed feeds. If corn is used as the principal ingredient in a concentrate mixture, its deficiencies in minerals and protein must be corrected with the addition of feeds high in minerals and protein. It is best to feed corn in the ground form.

Corn and cob meal is ground whole ears. It is used in dairy rations, adding bulk when other bulky feeds are not available. Its feeding value is somewhat less than an equal weight of ground corn. Although the cob is high in pentosans, it can be utilized to some extent by the cow's digestive system. Corn and cob meal should not be fed to young calves.

Grain sorghums are a very important feed in the midwest and southwest because of their drought resistance. They are not quite as palatable as corn but have a feed value which is about equal to it. These grains are used as a substitute for corn in the ration of dairy cattle, as well as other farm animals.

Barley is nearly equal to corn in feeding value for dairy cattle and, therefore, is a practical substitute for it. It can be used pound for pound as a corn substitute. Barley should be ground to a medium fineness or crushed before it is fed.

Hominy feed is a mixture of corn bran, corn germ, and part of the starchy portion of the kernel. It has relatively the same feeding value as corn meal and can be substituted for it. Hominy is kiln-dried and, therefore, keeps better in storage than ground corn.

Corn gluten feed is corn bran mixed with corn gluten meal. Both are by-products in the manufacture of starch and glucose. Corn gluten meal is higher in feeding value than corn gluten feed. Neither corn gluten feed nor corn gluten meal should be used as the sole substitute for corn in the dairy ration.

Oats are slightly higher in fiber than other cereal grains, but somewhat higher in protein than corn. Oats are a very desirable ingredient of the dairy ration. Oats add bulk to a dairy ration and they are relatively high in minerals.

Wheat is higher in protein, but contains less starch than corn. When wheat is available and price permits, it can be used to make up one-third of the concentrate mixture.

Wheat bran is a by-product of flour manufacture. It is a laxative, bulky feed, and high in minerals except calcium. It should be fed with other concentrates.

Wheat middlings also are a by-product of flour manufacture. They are higher in total digestible nutrients and protein than wheat bran. They make a satisfactory feed for dairy cattle but always should be fed with other concentrates.

Rye is comparable to other cereal grains in furnishing nutrients but is not so palatable. It should not be fed in large amounts to dairy cattle, because it is likely to cause digestive disturbances. If it contains ergot, abortions may occur.

Screenings represent a mixture of materials obtained in the process of cleaning grain or floor sweepings. They contain weed seeds, chaff, grain hulls, dust, dirt, and broken, imperfect, or immature grain. If one is to use screenings, he should check carefully the chemical analysis, composition, and weed seed content.

Cottonseed meal used to be the principal protein supplement all over the country, but in recent years it has been replaced to a considerable extent by soybean oil meal, except in the Southern States. Cottonseed meal is one of the best sources of phosphorus.

Linseed oil meal is one of the most popular of the protein supplements. It is palatable, laxative, and soothing to the digestive tract.

The solvent process product has had much more fat removed than that made by the expeller process so it is not valued as highly by many feeders. Linseed oil meal is high in phosphorus and particularly useful in fitting rations and for cows on official test.

Soybean oil meal is a by-product in the extraction of oil from the soybean. It is equal in feeding value to linseed oil meal and cottonseed meal as a protein supplement. Soybean oil meal is palatable, highly digestible, and provides a rich source of phosphorus. Cows can eat large amounts of it without injury to themselves or to the quality of milk or butter. It is now the principal protein concentrate used in many areas.

Ground soybeans are a good dairy feed. They are somewhat higher in fat and total digestible nutrients but slightly lower in protein than soybean oil meal. Ground soybeans are well liked by dairy cows, but if eaten in large quantities, tend to produce soft butterfat.

Beet pulp is a palatable, bulky, and a slightly laxative feed. It may be fed either wet or dry. Beet pulp may be used as a silage substitute although it is more expensive.

Citrus pulp is a by-product of the citrus fruit industry. It has about the same feeding value as beet pulp and is high in vitamin C. Citrus pulp is reasonably palatable and adds bulk to the dairy ration. It can be fed dry or wet and is used frequently as a part of the concentrate mixture.

Distillers' dried grains are a by-product of the distilling industry. After the starches have been removed from rye and corn, they are dried and sold as distillers' dried grains. Distillers' dried grains made from corn are higher in feeding value than those made from rye. They are relatively high in protein and add bulk to a ration when mixed with other feeds.

Wet distillers' grains are similar to distillers' dried grains except that they contain about 75 per cent moisture and so have one-fourth the feeding value of distillers' dried grains. They should be used within a convenient hauling distance of a distillery because of their perishable character.

Molasses is an excellent conditioning feed and is very palatable. It is very low in protein and furnishes only three-fourths as much total digestible nutrients as corn. Molasses is also high in minerals and is laxative.

FORAGES. The term forage refers to those plants which are fed to livestock in the form of hay, silage, or pasture. Forages generally are lower in total digestible nutrients and much higher in crude fiber

than the concentrates. Forages are divided into legumes and grasses. The *legumes* are those plants which have nodules on their roots. These nodules contain bacteria which fix atmospheric nitrogen which is used by the plant. Plants included in this group are alfalfa, the clovers, the beans, including soybeans, the peas, lespedeza, birdsfoot trefoil, and vetch. These crops generally are higher in protein and minerals than the grasses.

Although technically the classification *grasses* includes corn, the small cereals, and the sorghums, in general usage it refers to such crops as timothy, bromegrass, orchard grass, bluegrass, etc. The small cereals which are used for forage include oats, wheat, rye, and barley. Corn generally is placed in a classification by itself. The sorghums include sudan grass, sorghum, and millet.

Alfalfa is highly valued as a forage for dairy cattle. It is high in protein and calcium. Alfalfa also is palatable and has a laxative effect.

Clover is almost as good a forage as alfalfa. The protein content is somewhat less than alfalfa, but this forage is equally as palatable.

The *soybean plant* is an excellent forage. It is equivalent to alfalfa for milk production.

Timothy is a very good forage for dairy cows. It is inferior to the legumes, being lower in protein and containing less calcium. It also is less palatable and less laxative than the legumes.

Prairie hay is a very important forage crop in the Western States. When harvested at an early stage of maturity it is equal in feeding value to timothy and can be used as the only forage for dairy cattle. When harvested at a late stage of maturity, prairie hay is low in feeding value and palatability.

Mixed forage, with 50 per cent or more legumes, is an excellent feed for dairy cows. It contains more protein than timothy but less than the legumes. It is slightly higher in total digestible nutrients than alfalfa.

Corn stover is dried corn stalks with the ears removed. It is low in protein and not very palatable. It is not a good forage for dairy cows.

Straw is a poor dairy cow forage. It is low in protein, unpalatable, and constipating.

Silage is a very desirable winter forage for dairy cows. It is succulent and laxative. Hay-crop silage is finding an important place in the dairy feeding program. It is higher in protein and costs less per lb than corn silage. Corn or sorghum silage is an excellent source of carbohydrates in the dairy feeding program. Good hay-

crop silage and good hay together can provide 80 per cent of a cow's digestible nutrient requirement.

Roots and tubers, such as mangels, carrots, and rutabagas, are an excellent but expensive substitute for silage. They are relished by cows and are laxative and succulent. They do not, however, have a place in the economical feeding of livestock in this country.

Potatoes are a reasonably good substitute for silage if available at a reasonable cost. Heavy feeding may cause scouring and produce off-flavor milk.

The Use of Forage in the Ration. The term forage is now being used in the place of roughage in connection with livestock feeding. The purpose of this is to put greater emphasis on quality. Forage is the basic ingredient in a sound dairy feeding program. It is the most important single feed in the dairy ration. The cow's complete digestive tract, which will hold up to 320 qt, was developed to handle large quantities of forage. In the present day high-producing cow, however, even this capacity is inadequate to handle enough forage to meet the nutrient needs. This problem usually is met partially by feeding higher quality forage and partly by feeding concentrates.

Hay, pasture, and silage are the three types of forage generally used in feeding dairy cattle. All can be fed in large amounts. Quality has a tremendous effect on feeding value, because it affects both the digestible nutrient content of the forage and the amount that the animal will consume. Forage quality is affected by:

1. Time of cutting or grazing
2. Method of curing
3. Variety and species
4. Fertility of soil

TIME OF HARVEST. This is a very important factor in determining forage quality. According to the results of Reid at Cornell University, the total digestible nutrient content of first cutting forage decreased approximately 0.5 per cent on the dry basis for each day of delay in cutting. The digestible protein content also decreased at a fairly rapid rate. Cutting date was found to be a better index of nutritive value than stage of maturity. Consumption of first cutting hay harvested July 15 was only one-half of that harvested on June 1. Second crop forage did not decrease very rapidly in nutritive value with advancing maturity. Table 18 summarizes these results.

The most desirable cutting date is a compromise between decreasing nutritive value and increasing yield per acre. This is illustrated

TABLE 18. THE NUTRITIVE VALUE OF FORAGE AS RELATED TO DATE OF HARVEST
(*Dry basis*)

	Non-legumes			Legumes		
Cutting Date	Growth Stage	T.D.N., per cent	Digestible Protein, per cent	Growth Stage	T.D.N., per cent	Digestible Protein, per cent
			First cutting			
June 1	Vegetative	70	13.5	Vegetative	70	18.7
June 15	Early head	63	10.0	Bud	63	14.5
July 1	Full bloom	56	6.7	Bloom	56	10.2
July 15	Mature	49	3.7	Mature	49	6.4
		Aftermath following regrowth for 5 to 9 weeks				
		58	10.0		58	14.3

Courtesy J. T. Reid, Cornell University.

by Fig. 25, which also was developed by Reid for New York State. Appropriate corrections would have to be made for other areas. Owing to the unpredictable nature of the climate in some areas, cutting dates might have less significance elsewhere. This decision will have to be made on the basis of conditions in each area.

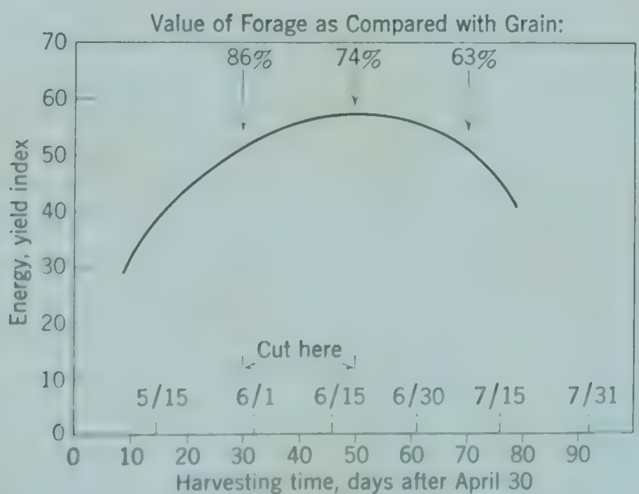

Fig. 25. Ideal time for harvesting forage. Energy yield index = dry matter yield × energy concentration. (Courtesy J. T. Reid, Cornell University.)

In general the recommended stages of maturity for harvesting the various species of forage for hay or silage are as follows:

Timothy—Just before bloom.
Clover—Two-thirds bloom, complete by full bloom.
Alfalfa—When new shoots appear at the crown or $\frac{1}{10}$ bloom.
Mixed forage—When most abundant legume is at proper stage.

It is always desirable, weather permitting, to begin harvest somewhat earlier than the above schedule. Because considerable time may be required to harvest the entire crop, the last part harvested may be too mature.

SPECIES. Species is less a factor in determining quality than is the time of cutting and methods used in harvesting. Although legumes may contain slightly less total digestible nutrients than nonlegumes of equal quality, they do contain a higher percentage of protein and calcium and usually produce a larger yield per acre, particularly in dry seasons.

SOIL FERTILITY. Fertility affects the type of species that will predominate on a certain soil, the yield per acre, and to some extent the chemical composition of the plant itself. As the yield per acre increases, the crop becomes more difficult to harvest and quality may deteriorate. High fertility may increase the content of certain elements and decrease the level of others.

METHOD OF HARVESTING AND WEATHER CONDITIONS. These factors must be considered together in their effect on forage quality. With favorable weather any good method of preserving forage will produce an excellent product with a minimum of loss. During unfavorable weather, however, losses in hay making may be very great. Although time of harvest, species of plant grown, and soil fertility are controllable to a considerable extent, they still are influenced by weather. The making of hay-crop silage and the drying of hay with heated or unheated air are for the most part attempts to overcome the deleterious effects of unfavorable weather.

Hay quality depends to a considerable extent upon leafiness and color. The leaves are much higher in digestible nutrients and lower in fiber than stems. A loss of color is indicative of a low carotene content and a loss of soluble nutrients due to leaching. Rain, overcuring, and storing when it is too green all lower hay quality. Although high-quality hay cannot be excelled as a forage for the winter feeding of dairy cattle, it is very difficult to make in certain areas.

In selecting the method of harvesting to be used, considerable attention should be given to the kind of equipment and storage space

available on the particular farm and the kind of weather likely to be encountered during the harvest season. Table 19 shows how the amount of nutrients saved for feeding is affected by weather and method of harvest.

PASTURE. Pasture grown on well-fertilized soil and grazed at the proper stage of maturity is the ideal forage for the dairy cow. It also is the most economical source of feed nutrients. The average total feed cost of milk produced on pasture is approximately half that produced during the winter barn-feeding season.

A cow on abundant pasture will eat 120 to 150 lb per day. In order to harvest this amount she must graze several hours. When the

TABLE 19. DRY MATTER AND FEED NUTRIENTS SAVED IN ALFALFA MIXED FORAGES HARVESTED AND STORED IN DIFFERENT WAYS

	Field-Cured Hay		Barn-Finished Hay			Artificial Dehydration
	Rained On	No Rain	No Heat	Heat	Silage	
Dry matter, per cent	63.4	79.0	81.0	84.8	83.2	90.3
Protein, per cent	53.9	72.3	76.0	78.7	83.1	81.8
Carotene, per cent	0.9	3.2	6.3	10.4	19.2	23.5
Total digestible nutrients, per cent	57.9	74.5	76.0	79.5	80.5	86.9
Net energy, per cent	52.8	70.4	71.4	74.5	80.5	81.9

Adapted from *U.S.D.A. Tech. Bull. 1079,* 1954.

pasture is poor and the forage scanty, a cow uses much more energy in an effort to obtain enough feed, and has less energy for milk production. A cow may need to graze more than twice as long on a fair pasture than on a good one. On a poor pasture, she may not be able to obtain enough feed at all.

Most legume and grass mixtures provide excellent pasture. Ladino clover and timothy or bromegrass are the species used for pasture seeding in much of the country. In certain sections, however, other mixtures are more suitable. Well-fertilized and well-managed pastures may yield adequate protein to meet the requirements for high production. Young pasture grass growing actively contains 16 to 20 per cent of very digestible protein when dried to a hay basis, whereas the protein content of a mature, coarse pasture may fall to a very low level and will be relatively indigestible. Many dairymen fail to

take full advantage of early, well-fertilized pasture growth. Dairy cows on such pasture are often fed a grain mixture containing much more protein than is necessary. This practice does not increase production and is uneconomical.

Adequate pasture throughout the grazing season is necessary for maximum economical production. Rye will extend the pasture season by providing earlier grazing in the spring and later grazing in the fall. Sudan grass and millet may provide a late summer pasture when the feeding capacity of permanent and rotated pastures decrease.

There is an advantage in feeding hay or hay-crop silage to cows on pasture. This practice will encourage cows to eat more total forage. Also, as the feeding capacity of pasture declines, cows will eat increasing amounts of hay or silage, thus maintaining a higher level of production. Hay fed on pasture may be a factor in maintaining body condition, as well as in controlling bloat.

HAY-CROP SILAGE. Hay-crop silage is now a very important feed for dairy cattle over much of the United States. Proper ensiling of legumes and grasses conserves more of their nutritional values than any other form of forage preservation except drying with heat. Even allowing for 10 per cent loss of nutrients in the preparation of hay-crop silage, properly ensiled green material can satisfactorily replace some of the concentrates, all of the corn silage, and most of the hay.

Hay-crop silage has an additional advantage in that first cutting forage can be harvested when adverse weather may interfere with good hay-drying conditions. Preservatives may or may not be added in making hay-crop silage. The use of materials such as molasses, citrus pulp, grain, and sodium metabisulfite does not guarantee good silage but, in general, the quality and palatability are improved and the feeding value is increased. Legume and grass silage is the nearest thing to green forage that can be produced on the average dairy farm. On many farms hay-crop silage has become the basic feed for barn feeding dairy cows, with hay, corn silage, and concentrates providing the necessary supplements.

CORN SILAGE. Corn silage has an important place in the ration of the dairy cow. Corn produces heavy yields per acre and is a cheap and important source of high-energy feed. Corn silage frequently is the dairymen's cheapest source of carbohydrates. It is an important crop in the rotation because of its value as a "clean-up" crop. Its disadvantages include: (1) an annual crop, (2) low in protein, carotene, calcium, and phosphorus as compared to grass-legume silage, and (3) more expensive than hay-crop silage.

FORAGE REQUIREMENTS. These requirements are determined by economic conditions. It formerly was stated that dairy animals should receive all of the forage that they would eat and that the size of the herd should be determined by the forage producing capacity of the farm. Although both of these statements may still be true for dairy farms producing milk for a low price market, they are not true for dairy farms located in high-cost areas near centers of population. In fact, in such areas many large dairy herds are operated profitably on small areas of land with all or nearly all of the feed being purchased. For such operations the rule has been to feed at least 1 lb of hay or hay equivalent per 100 lb of body weight per day. The remainder of the ration is made up of concentrates or forage substitutes, the cost of digestible nutrients being the principal factor in deciding what to feed. In some recent experimental work, very satisfactory results were obtained when milking cows were fed rations varying from 20 per cent concentrate and 80 per cent forage to 80 per cent concentrate and 20 per cent forage. The high concentrate ration gave the greatest production and it was concluded that under conditions of relatively low-cost concentrate high cost forage, this might be the most profitable combination.

Under usual farm conditions, however, dairy cows should be fed all of the forage they will eat. If enough is not available on the farm, then animals must be sold or forage purchased. If needs can be estimated ahead, it is often possible to adjust forage production by heavier fertilization, purchasing or renting more land, and by seeding more forage crops. Under any condition it is desirable that both the requirements and supply be estimated.

Thumb rules may be used to estimate forage requirements. When cows are fed all the silage and good mixed hay twice a day that they will eat, they will consume 4.5 lb of silage and 1 lb of hay daily per 100 lb of live weight, in addition to the usual amount of a concentrate mixture. Thus, the average 1,000-lb cow will consume approximately 10 lb of hay and 45 lb of silage per day. If no silage is fed, the average 1,000-lb cow will consume approximately 25 lb of hay per day. When hay-crop silage is the only forage fed, a cow will require approximately 7.5 lb per 100 lb of liveweight per day, or a 1,000-lb cow will require approximately 75 lb daily. Cows will consume more than these amounts if palatability and quality are above average.

The first step in meeting feed needs is to inventory the forage available and to estimate the amount required, with liberal feeding, to carry the livestock on hand through the feeding period. Forage

needs are evaluated best in terms of hay equivalent. Hay equivalent is the feeding value of various forages expressed in terms of hay. For example, 3 tons of silage are equal to 1 ton of hay. Hay equivalent factors for common forages are used in Table 20 to calculate the hay equivalent of 30 tons of each.

By using the hay-equivalent factors, one can estimate the tons of hay equivalent available for feeding. Additional forage allowances should be made for the pasture-feeding period if hay or silage is fed in addition to pasture.

In order to estimate the total herd hay-equivalent requirements, one should total the live weights of all cows in the herd. To this add the weights of bulls and the sum of the estimated weights of

TABLE 20. FORAGE IN TERMS OF HAY EQUIVALENT

Forage	Hay-equivalent Factor		Tons of Forage		Tons of Hay Equivalent
Hay	1.0	×	30	=	30
Silage	0.33	×	30	=	10
Corn stover	0.6	×	30	=	18
Straw	0.5	×	30	=	15
Root crops	0.2	×	30	=	6

calves and heifers halfway through the feeding period. The growth chart in Table 14, Chapter 7, will be of help in arriving at this estimate. Finally, the total estimated weight of the herd is divided by 100, and this value is multiplied by 2.5 to give the daily hay-equivalent requirement. The daily hay-equivalent requirement is multiplied by the estimated length of the feeding period to give the pounds of hay needed for the season. This value is divided by 2,000 to convert the requirement figure into tons.

After calculating the estimated herd forage requirement, it is advisable to determine forage available for feeding purposes. To determine the approximate number of tons of hay in a mow, multiply the length by the width by the height (all in feet) and divide the product by the number of cubic feet per ton for the kind of hay and the length of storage as shown in Table 21. Various hay-making practices and methods of storing may vary these figures. Silage varies materially in weight depending on length of cut, type of ensiled material, and moisture content. Therefore, the dairyman should use Table 22 only as a general guide.

The average silo will hold about the same amount of hay-crop silage as corn silage. If immature corn is ensiled, add 10 to 15 per

cent to the above weights. If the grain is unusually heavy in proportion to the stalk, add 5 to 10 per cent to weights given in the table. If the corn is past the usual stage of maturity and contains less than the usual amount of water, deduct 10 to 15 per cent. The following

TABLE 21. APPROXIMATE VOLUME OF HAY PER TON

Kind of Hay	Cubic Feet per Ton of Hay	
	Settled 1–3 Months	Settled Over 3 Months
Alfalfa	485	470
Clover	512	500
Timothy	640	625
Chopped hay	225	225
Wild hay	600	450

TABLE 22. APPROXIMATE TONS OF SILAGE IN UPRIGHT SILO

Height of Silo, feet	Diameter of Silo					
	10 ft	12 ft	14 ft	16 ft	18 ft	20 ft
20	30	42	58	75	95	118
22	33	47	64	84	105	130
24	36	52	70	92	116	144
26	38	54	74	96	122	150
28	43	62	84	109	138	170
30	46	66	90	118	149	184
31	48	69	93	122	154	190
32	50	71	97	126	160	196
33	51	73	100	130	165	202
34	53	76	103	135	170	209
35	54	78	106	139	176	215
36	56	80	110	143	181	221
37	58	83	113	148	187	228
38	60	86	117	152	192	234
39	62	88	120	156	198	240
40	63	90	123	160	203	246

table shows the approximate tons of silage in a trench silo of different cross-section dimensions.

After the weight of each type of forage is estimated, it is placed in the second column of a table similar to Table 20 and multiplied by the appropriate factor in the first column. The product is placed in

the third column. The sum of this column gives the total hay equivalent available. By comparing this value with the total estimated needs, one can see how many tons of hay equivalent are needed or are held in excess of needs.

TABLE 23. ESTIMATED SILAGE WEIGHT IN TRENCH SILO

Depth, feet	Top-width, feet	Bottom-width, feet	Length of Trench Silo 30 ft	40 ft (*Tons of silage*)	50 ft
10	18	10	75	100	125
10	15	8	60	80	100
10	11	6	45	60	75
8	15	8	48	64	80
8	12	7	39	52	65
8	10	6	33	44	55
6	13	8	33	44	55
6	11	7	27	36	45
6	9	6	24	32	40

Pasture requirement per cow will be influenced by the type of stand, level of fertilization, amount of rainfall, size of cow, and method of grazing. Average requirement per cow will be approximately as follows:

	Acres per cow
1. Rotated, improved pasture (Plowed, seeded, and fertilized)	0.75
2. Improved pasture (Plowed, seeded, and fertilized)	1.0
3. Fertilized native pasture	2.5
4. Unimproved native pasture	5.0

Balancing Rations. Every student of dairy science should know how to balance a ration for a dairy cow according to the feeding standard, even though a simplified procedure is used in general practice. In balancing a ration the needs of the cow for maintenance, milk production, growth (if the animal is still growing), and for pregnancy (if during the last 2 or 3 months before calving) are calculated and added. The requirements are obtained from one of the feeding standards.

TABLE 24a. CALCULATION OF REQUIREMENTS

	Digestible Crude Protein, pounds	Total Digestible Nutrients, pounds	Calcium, grams	Phosphorus, grams
Maintenance 1,400 lb body weight	0.80	9.4	11	11
Lactation 50 lb 4 per cent milk	2.25	16.0	50	35
Total requirements	3.05	25.4	61	46

TABLE 24b. RATIONS MEETING REQUIREMENTS OF COW IN TABLE 24a

Feeds	Weight, pounds	Digestible Crude Protein, pounds	Total Digestible Nutrients, pounds	Calcium, grams	Phosphorus, grams
		Ration A			
Alfalfa hay	35	3.82	17.7	234	38
Barley	10	1.00	7.8	3	18
Total		4.82	25.5	237	56
		Ration B			
Timothy hay	14	0.42	6.9	22	9
Corn silage	42	0.50	7.7	19	13
Corn and cob meal	11	0.59	8.1	2	11
Soybean oil meal	4	1.68	3.1	6	12
Limestone	0.1	...	...	17	...
Total		3.19	25.8	66	45
		Ration C			
Alfalfa hay	20	2.18	10.1	133	22
Corn silage	50	0.60	9.1	23	16
Corn	4	0.27	3.2	0.4	5
Oats	4	0.38	2.8	2	6
Total		3.43	25.2	158	49

One of the most reliable feeding standards is given in the *National Academy of Sciences–National Research Council Publication 464*, "Nutrient Requirements of Dairy Cattle," 1956 revision. This feeding standard (minimum values–no margin of safety), the average composition and digestible nutrient content of common feedingstuffs,

and other useful information from this publication are given in the appendix.

In order to show the first step in balancing a ration, the requirements of a 1,400-lb cow, producing 50 lb of 4 per cent milk, are calculated in Table 24*a*. Requirements as given in Appendix C were used. The objective is to combine forages and concentrates in a palatable ration which meets the requirements as calculated but does not provide a costly excess. When the body weight or the butterfat percentage of milk falls between the figures given in the requirement table, one must interpolate to get the correct requirements.

In this example, forage varied from high-protein alfalfa hay to low-protein timothy hay and corn silage. As can be seen, the need for a high-protein concentrate depended on the protein content of the forage fed. In balancing rations, the nutrients supplied by the forage are calculated first. Then the difference between total requirements and those furnished by the forage are determined. Finally, a combination of concentrates is worked out to supply the differences. The approximate T.D.N. needs generally are worked out first and then the protein content is adjusted. When the total for protein is too high, part of a high-protein feed is replaced by a low-protein ingredient. When the total for protein is too low, then some of a low-protein ingredient is replaced by a high-protein feed. After one has had a little experience with such calculations, the proper adjustments can be made very readily.

Determining Protein Content of Concentrate Mixture. Although the use of the feeding standard is relatively accurate, its use is impractical under farm conditions. The general practice is to feed the same concentrate mixture to all cows, varying only the amount fed. In order to do this economically, the mixture should provide only those protein needs which are not met by the forage plus a reasonable amount of safety. Table 25 provides the generally recommended levels of protein which either home-mixed or purchased concentrates should contain when fed to milking cows getting various types of forage.

Home-mixing of Concentrates. In many parts of the country commercially manufactured dairy feeds are becoming very widely used. This use is particularly widespread in those areas where little grain is grown and on those farms where large herds are kept and most or all of the available land is in forage production. In other areas of the country, home-grown cereal grains are ground on the farm and

mixed with the appropriate amount of an oil meal or a commercial 32 or 36 per cent protein supplement. The grinding may be done by a farm-owned mill or a portable mill which visits the farm on a definite schedule or on call. More recently such outfits also are equipped with mixers and equipment for adding molasses to the mixtures. Operators of such equipment frequently carry the protein concentrate and molasses and sell them as part of the mixing service.

Many operators of feed stores in grain producing areas grind the dairyman's grain and use it in making the type of mixture needed. This type of service permits the use of a greater variety of ingredients and the making of a high-quality product at a reasonable price.

TABLE 25. RECOMMENDED PROTEIN CONTENTS OF CONCENTRATES TO BE FED WITH VARIOUS TYPES OF FORAGE

Kind of Forage	Crude Protein, per cent	Digestible Protein, per cent
Nonlegume hay and corn silage	20	16.0
Mixed hay, containing 30 per cent legumes and corn silage	18	14.4
Nonlegume hay and grass silage (clover and timothy)	18	14.4
Clover hay and corn silage	16	12.8
Mixed hay containing 30 per cent legumes and grass silage (clover and timothy)	14	11.2
Legume hay and grass silage (clover and timothy)	12	9.6

Many of the ingredients which a particular dairyman buys are purchased by the store from some other dairymen in the area. This procedure results in considerable savings, because the charges of various middlemen and transportation costs are minimized.

Typical mixtures for various types of uses are given in the appendix. These vary from very simple mixtures as given in Appendix C, to commercial type mixtures as given in Appendix D. The protein content of such mixtures is adjusted in much the same way as when calculating a ration for an individual cow according to the feeding standard. The general practice is to add common salt to such mixtures at the rate of 1 per cent. Iodine and cobalt are added in certain areas where deficiencies occur. Calcium and phosphorus supplements are added when they are likely to be needed.

Feeding Tables. In general practice, cows are fed all of the forage they will eat, and concentrates are allotted on the basis of judgment

or feeding tables, charts, or mechanical gadgets. These ordinarily consider the amount and test of the milk produced and the quality of the forage fed. Two such tables are given in Appendix E. One is for barn-feeding cows and the other is to be used in feeding cows on pasture.

Experience and Judgment. Actually both the feeding standard and the feeding tables are only guides. Each cow is an individual and varies from every other cow. An experienced herdsman will depend on many things, especially level of production, body condition, appetite, and condition of feces to guide him in feeding dairy cattle.

The stimulus to secrete milk comes from the endocrine system of the cow, not from the feed. In early lactation, a high-producing cow will secrete milk at the expense of body reserves. Thus when a milking cow is losing condition, she is not eating enough to take care of her needs. If she is gaining in condition, she is eating more than enough to meet her needs. If a cow increases in production when given more concentrates, it is generally an indication that more feed is needed. If a cow is given more feed, but instead of increasing in production puts on more condition, the extra feed was not needed, unless the cow was in poor condition. In general, more concentrates can be fed safely as long as an animal eats with a good appetite. Experience, however, can help a herdsman tell when to level off or even decrease feed intake. The feces of a normal cow are slightly loose. Hard feces or very loose feces indicate that something is wrong, particularly with rumen fermentation. If the feces are hard, the condition usually is a result of feeding a mature grass hay and a small amount of nonlaxative concentrate mixture. The condition generally can be corrected by feeding some legume hay, liberal quantities of concentrates, and such feeds as dried beet pulp, wheat bran, and linseed oil meal. Quite often inadequate water intake is found to be the cause of such a condition. Diarrhea usually results from the feeding of excessive quantities of very laxative feeds such as very young pasture, from feeding spoiled feeds, and from digestive upsets. Any abnormal bowel condition should not be allowed to continue.

Above all, the dairyman must keep in mind the economics of milk production. The herd should be fed so as to produce milk as profitably as possible. Maximum production is not always the most profitable level of production. A good dairyman tries to plan his feeding program on the basis of the most economical source of nutrients which can be used in a ration that will meet all the nutrient needs of his herd in the proper proportions.

QUESTIONS

1. For what purposes does the dairy cow use feed?
2. What feed nutrients are needed by the cow? What is the function of each?
3. What characteristics of a feed affect its consumption and utilization?
4. Define or explain the following: proximate analysis; digestion coefficient; digestible protein; total digestible nutrients; gross energy; metabolizable energy; net energy; heat increment; digestible energy; and digestible dry matter.
5. What is meant by the term concentrate feed?
6. What is meant by the term forage?
7. What factors affect the nutritive value of forage crops? How?
8. Calculate the forage needs for a 210-day winter feeding period in terms of hay equivalent for a herd consisting of 50 Holstein cows and 25 head of young stock evenly distributed from a few days of age to calving.
9. Calculate the total hay equivalent of 100 tons of red clover hay, 250 tons of corn silage, and 130 tons of hay-crop silage. How does this meet the forage needs as calculated in number 8?
10. Calculate a balanced ration for a 1,350-lb cow producing 75 lb of 3.7 per cent milk. Available are mixed hay (less than 30 per cent legumes), well-matured corn silage, corn, oats, wheat bran, soybean oil meal, common salt, and dicalcium phosphate.
11. What should be the crude protein content of a concentrate mixture to be fed with timothy hay and corn silage? With mixed clover and timothy (less than 30 per cent clover)? With alfalfa hay?
12. Formulate on a ton basis concentrate mixtures which will contain 12, 16, and 20 per cent crude protein.
13. Using the feeding tables in the appendix, determine how many pounds of concentrates should be fed daily to a cow producing 75 lb of 3.7 per cent milk if average quality hay is fed.
14. How many pounds of concentrate should the cow in number 13 be fed if she is allowed all she will eat of excellent pasture?
15. What guides does an experienced herdsman use in determining the nutrient needs of a dairy cow?

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CHAPTER **9**

Dairy Cattle Housing and Feed Handling

The trend in dairy farm structures is toward low-cost, loose housing and away from the expensive stall barn. Forage feeding is rapidly changing from the use of the hay and silage fork to self-feeding from storage or by mechanical feeders. Loose housing and mechanized feeding generally are coming to be associated with the management of larger herds.

The Stall Barn. This conventional type of structure is found in all parts of the United States. It was the generally accepted type of dairy cattle housing up until recent years. This type of structure still has a place on certain farms, particularly in colder climates, where a purebred herd is to be displayed to advantage, or where the dairyman has a strong aversion to loose housing. When a good stall barn is already on the farm, it usually must be used as originally planned. Sometimes, however, such a structure can be used to advantage as a milking or calf barn.

The construction and use of stall barns is related to winter temperature and relative humidity. Figure 26 shows zones of similar winter temperature and relative humidity. In zones 1 and 2, cows in stall barns spend most of the winter indoors except for being turned out for exercise when the weather is not too severe. In zones 3 and 4, loose housing frequently is used with stall barns. For example the cows may be put into the stall barn for grain feeding and milking.

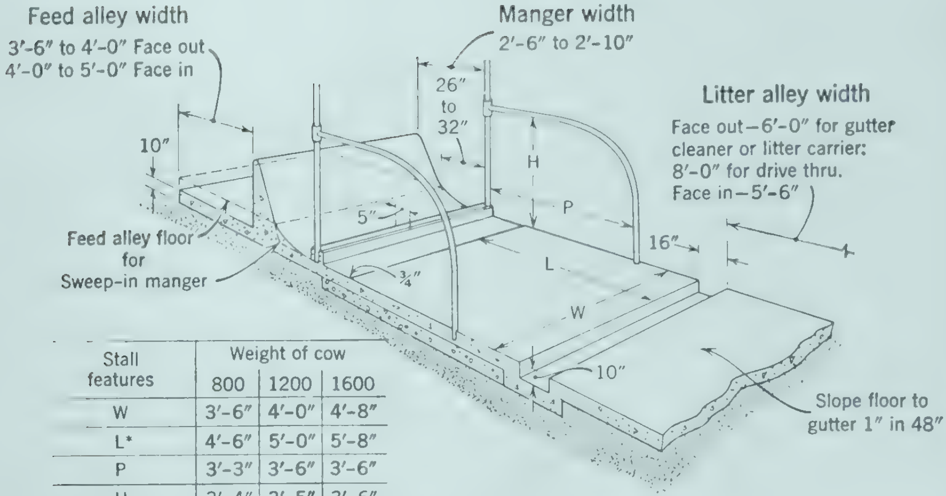
Fig. 26. Zones having similar winter temperature and relative humidity. (Courtesy Babson Bros. Co.)

then turned out to eat hay and silage in an open shed or from unsheltered feed troughs. Actually, however, loose housing can be used successfully even in zones 1 and 2.

Stall barns usually are of either one- or two-story construction. The one-story structure generally has hay, concentrate, and bedding storage adjacent to where the cows are housed. The two-story barn generally has storage for these items in the top floor and stalls for the cows in the lower. Both types of barns require a conveniently located milk room and calving pens. Young stock may be housed in separate facilities in the dairy barn or in another structure.

The stall dairy barn should be located on a site which has good drainage on all sides. The exercise lot should be particularly well drained and paved if possible. The barn should be located so that prevailing winds will not carry objectionable odors to the dairy barn or odors from the dairy barn to the dwelling.

Stalls may be arranged so that cows face in or out. The better arrangement will depend on the methods of feeding, gutter cleaning, and milking that are to be used. There is often considerable advantage in being able to drive a manure spreader or truck through the barn, which requires that the cows face out. This plan also has the advantage of preventing the splattering of manure on the barn walls. Stalls should be of liberal size in order to increase cow comfort and minimize udder injuries. Recommended dimensions for con-



Stall features	Weight of cow		
	800	1200	1600
W	3′-6″	4′-0″	4′-8″
L*	4′-6″	5′-0″	5′-8″
P	3′-3″	3′-6″	3′-6″
H	3′-4″	3′-5″	3′-6″

*4″ may be added to stall length if electric cow trainers are used.

Fig. 27. Typical cow stall showing recommended minimum dimensions for cows of different weights. High front manger is shown with solid lines; sweep-in type with dotted lines. (U.S. Department of Agriculture Information Bull. 123.)

ventional stalls, feed and litter alleys, mangers, and gutters are shown in Fig. 27.

Stall lengths may be increased 4 in. if a cow trainer is used. This device consists of a $\perp$ shaped wire suspended 1½ to 3 in. over the cow's back, 18 to 24 in. back of the stanchion line and connected to an electric fence controller. This trainer prevents much soiling of udders and hindquarters which is so common with certain cows - especially cows kept in stalls which are too long. The problem of cows varying in size can be handled by varying the length of the stall platform from one end of the stall row to the other and by having the stanchions fitted with alignment devices. Gutters should be at least 8 in. deep on the litter alley side and at least 10 in. deep on the stall side. They should be 16 to 18 in. in width and constructed to accommodate a gutter cleaner. Steel plates which will prevent slipping should be provided for crossing points.

The high front manger is more expensive to construct and requires more labor in feeding and cleaning. It has some advantage from the disease control standpoint. The sweep-in manger may vary from a flat floor to a feed alley which is elevated 10–12 in. Such alleys are very convenient for both feeding and cleaning operations.

Space for various types of dairy cattle should be provided on the basis of the following division of the herd:

Milking cows	50 per cent
Dry cows	5 to 8 per cent
Heifers 10 months to freshening	25 per cent
Calves 6 weeks to 10 months	12 per cent
Calves under 6 weeks	5 to 8 per cent

Provisions can be made for housing young stock and for maternity pens in the dairy barn or in another building. Young calves should be kept in separate pens until one week after milk or milk replacer feeding is discontinued. Recommended dimensions for pens for various aged animals are given in Table 26.

TABLE 26. RECOMMENDED DIMENSIONS FOR CATTLE PENS[a]

Type	Length and Width: Minimum, feet	Length and Width: Maximum, feet	Height, feet
Cow pens	10 × 10	12 × 12	4½
Individual small calf pens	6 × 4	6 × 6	4
Four-calf pens[b]	10 × 10	12 × 12	4½

[a] *U.S.D.A. Agriculture Information Bull. 123.*
[b] Allow 20 to 25 inches of manger per calf.

A well-planned stall barn with cows facing out is shown in Fig. 28. This barn is a two story structure with hay and bedding stored on the upper floor. Such a barn must be provided with a well-planned ventilation system. Ventilation is very important in cold climates, as it is necessary to get rid of the large amount of moisture produced by cows, maintain a temperature of 40° to 55° F, and prevent condensation on walls and ceiling. It is recommended that the ventilation system for each barn be designed specifically for it by a qualified person. Barn ventilation is not a serious problem in climates where windows and doors can be open much of the time. Dairy barns should be kept cool in summer by means of good ventilation, shade trees, and light-colored roofs and siding. High temperatures reduce milk production and make it unpleasant for the herdsman.

The milk room should be constructed so as to permit the production of Grade A milk under the regulations of the particular market where the milk is to be sold. In any case the milk room should provide adequate space for a bulk tank, the necessary cleaning

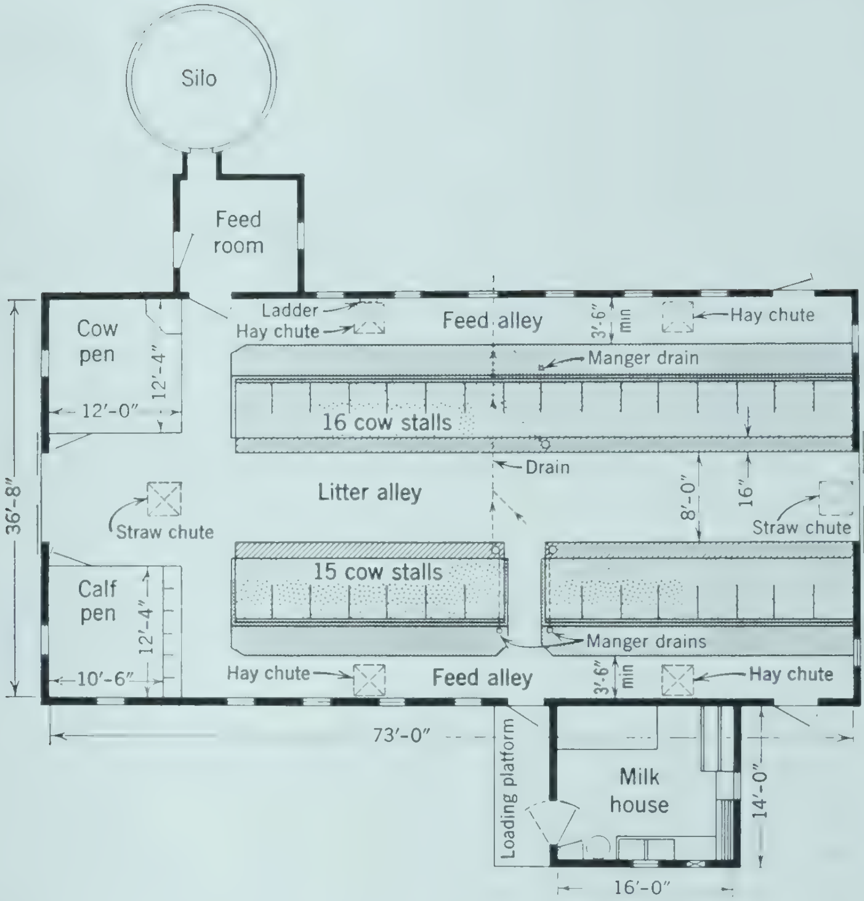


Fig. 28. Well arranged plan for a two-story, 31-stall barn. The litter alley shown is designed for drive-through cleaning. If a gutter cleaner is installed, the width of the alley may be reduced to 6 ft and the width of the barn to 34 ft. (U.S. Department of Agriculture Information Bull. 123.)

operations, and equipment storage. It should be well ventilated and well lighted, have smooth, easily cleaned light-colored walls and ceiling, and have the doors and windows screened against flies.

Loose Housing for Cold Climates. In this type of housing cows are kept in an open pasture or lot and allowed free access to shelter. They are milked in a separate or attached milking room. Cows handled under this system do not suffer in cold weather because they develop long coats and have shelter from the elements. They also are provided with some heat from the accumulated manure. Under good management cows remain clean. There is little trouble from stiff hocks, swollen knees, winged shoulders, and stepped-on

teats. Cows can be removed very quickly in case of fire. This system of handling cattle has both advantages and disadvantages as compared to the stall barn. Some of these are as follows:

Advantages

1. Hay and silage can be partly or completely self-fed.
2. Labor can be used more efficiently.
3. Tractor manure loader can be used to remove manure and clean feeding area.
4. Less investment per cow is required.
5. Cows have greater comfort and less injuries.
6. Ventilation is not a serious problem.
7. Greater flexibility in use of facilities.
8. Minimum need for lighting.

Disadvantages

1. Men who care for animals are more exposed to weather.
2. More bedding may be required with a poorly planned barn or poor management.
3. Cows in heat must be removed from herd.
4. Boss cows may be a problem.
5. Cows must be dehorned.
6. Difficult to show herd to advantage.

In northern states a loose housing set-up would include the following:

1. Loafing area for cows and one for young stock.
2. Forage and concentrate feeding facilities for cows and for young stock.
3. Storage space for hay, silage, and bedding.
4. Milking facilities which include concentrate feeding and storage.
5. Maternity, hospital, and calf pens.
6. Exercise lots.

A typical loose housing set-up for cold climate is shown in Fig. 29. Many other arrangements are just as satisfactory.

The Loafing Barn for Cows. This structure should provide 50 to 70 sq ft of shelter per cow. The floor can be earth, gravel, or concrete. The building should be high enough to permit a tractor loader to maneuver on a 3- to 4-ft manure pack. Posts or poles should be

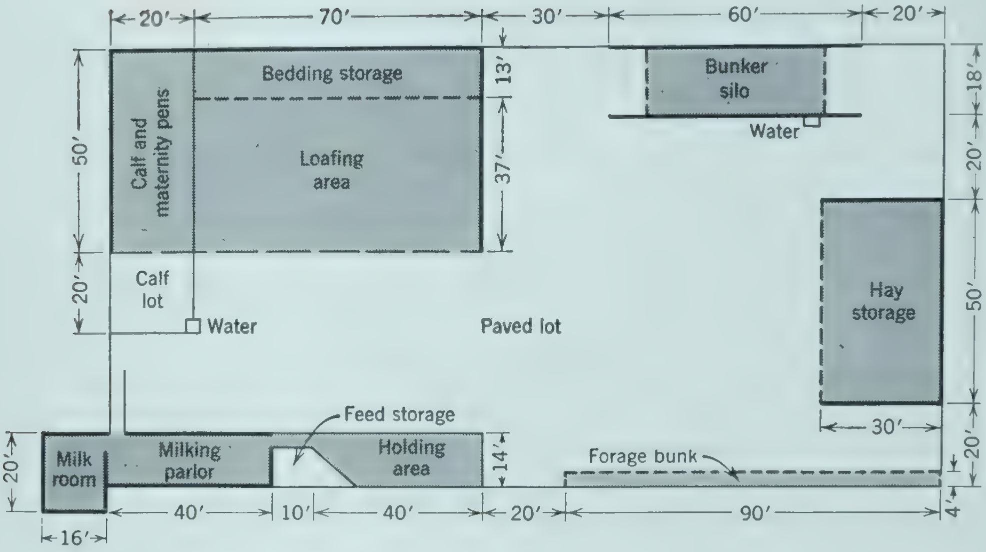


Fig. 29. A loose housing layout for a 35-cow herd. Silage may be fed from bunker silo or forage bunk. Green forage may be placed in forage bunk with self-unloading wagon. (Courtesy Babson Bros. Co.)

spaced at least 12 ft apart in each direction in order to facilitate the use of the tractor loader and manure spreader. Manure may be allowed to accumulate during cold weather. The building should be open on the south side if possible in order to take advantage of the heat from the sun in warming and drying the building and bedding during the winter months. Bedding requirements will depend on the type of bedding used, length of housing season, climate, and kind of management. Chopped straw, sawdust, and shavings are very satisfactory for this type of structure. The amount required will average from almost none in southern areas to 12 lb or more per cow per day in northern climates.

Lot areas should provide 100 sq ft of paving per cow where weather makes it necessary. Unpaved corrals or exercise lots should provide 300 to 500 sq ft per cow. Both should drain away from buildings at a 1-in. to 4-ft slope.

Feeding Area. In cold climates feeding facilities should be under a roof. The feeding area should be separate from the loafing area and have a paved floor and a post arrangement which will permit easy cleaning with the tractor loader or blade. Adequate hay and silage storage should be provided as conveniently as possible so as to minimize labor requirements for feeding. The amount of space

needed for storing adequate supplies of hay can be calculated according to information given in Chapter 8. The amount of concentrates to be stored will depend on the rate of feeding and the method of mixing or buying followed. Feeder space will be discussed later. Water should be provided near the feeding area, not in the loafing area. Either water bowls or tanks may be used. Bowls should be installed at the rate of one for every 25 cows. Provisions should be made to prevent freezing of watering equipment. The feeding area should be equipped with adequate lighting.

Loose Housing for Warm Climates. The loafing area in warm climates can be a corral or lot provided with suitable shade such as shown in Fig. 30. Such a structure should provide approximately 40 to 50 sq ft per animal and should be covered with a wood or a light-reflecting metal such as aluminum. Here the loafing area also can be used as a feeding area, but the feeding facilities should be placed some distance from the shelter. The feeding facilities will depend on the type of feeding program being used.

Feeding Facilities and Equipment. The general objective is to reduce the labor requirements for forage feeding as much as possible.

Fig. 30. A shade shelter such as this may be used to protect cows from hot sun in warm climates. (Courtesy University of Arizona.)

Fig. 31. Corral feeding is practiced in warm, dry areas. Hay is stored in open. (Courtesy Babson Bros. Co.)

Certain basic space requirements can be set for almost all conditions. If cattle have access to forage at all times, 12 to 18 in. of feeder space per cow is adequate. If it is fed in batches so that all animals eat at the same time, the space allowance must be increased to 24 to 30 in.

In warm, dry climates, baled hay may be stored in the open and fed as shown in Fig. 31. In other cases chopped hay or silage may be fed in mangers located along a roadway. One of the newest modifications of this type is the fan-shaped arrangement shown in Fig. 32. A side unloading wagon frequently is used for filling such mangers with chopped hay or silage. Baled hay has to be handled by hand.

In colder and more humid climates cows are sometimes fed hay from the type of structure shown in Fig. 33. The feeding fence is moved into the building as the hay is fed out. This provides more shelter space as the winter feeding season progresses. With certain changes, chopped hay may be used as well as baled.

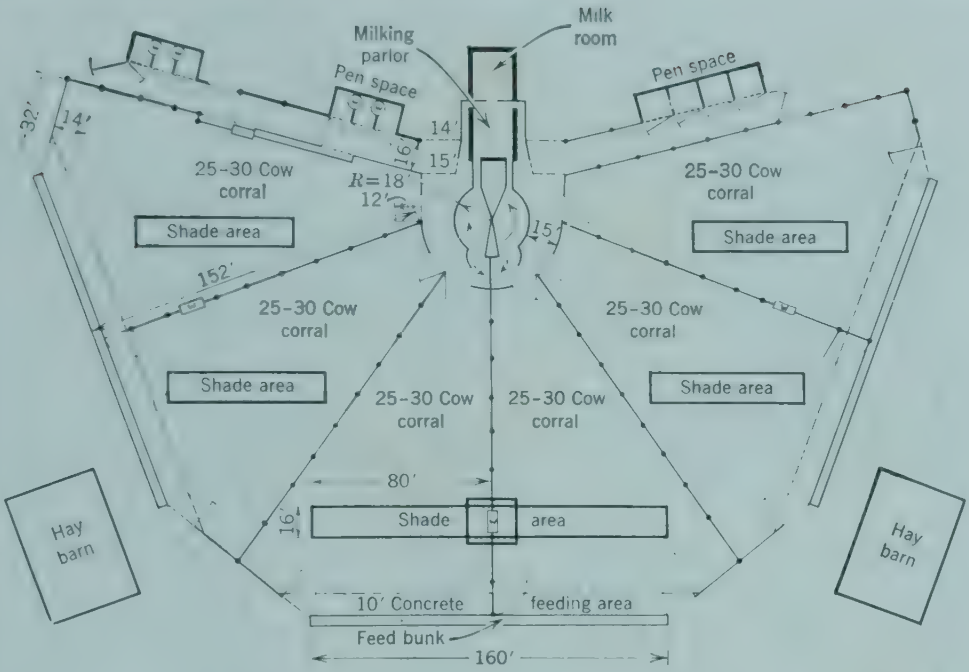


Fig. 32. A fan-shaped corral for a 150- to 180-cow milking herd. This arrangement is suitable for large herds maintained in warm climates. (Courtesy University of Arizona; Carl Lamar John, architect.)

Fig. 33. An economical hay barn which permits cows to eat from feed bunks adjacent to storage. (Courtesy Babson Bros. Co.)

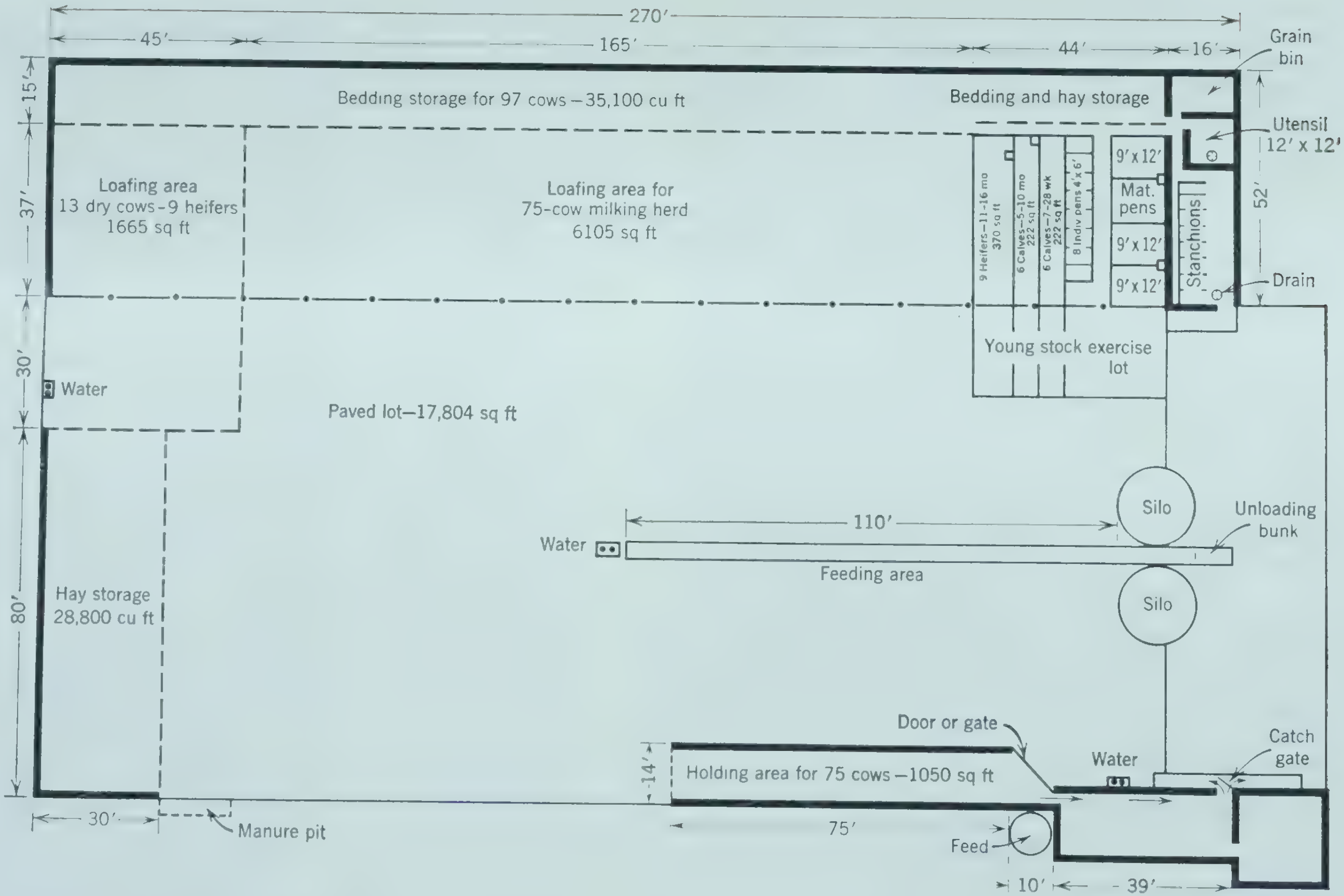


Fig. 34. This loose housing layout was designed for 75 cows but can be expanded to 150 cows by adding a duplicate set of buildings and facilities to the right. A central milk room would be used. (Courtesy Babson Bros. Co.)

Silage can be handled very economically in several different ways. One of the simplest is to let cows eat it out of a trench or bunker silo. Feeding is controlled by moving an electric fence or feeding gate along as the silage is removed. This type of operation usually requires that the bottom of the silo be paved and that the manure be removed frequently. In other cases the silage is removed from the silo and placed in a forage manger.

In still other situations, silage may be stored in tower silos from which it is removed by hand or mechanical unloader. In many cases the silage is carried from the silo chute and distributed the length of a manger by a mechanical feeder. An entire set-up of this sort can be controlled completely by push buttons and time clocks. The use of this type of arrangement in a typical loose-housing layout is shown in Fig. 34.

One of the latest developments in completely mechanized silage feeding is shown in Fig. 35. Silage from these airtight, bottom-unloading silos is placed on feeders which move around the base of each silo. This system apparently provides a very satisfactory feeding arrangement.

In planning mechanical feeding, it seems wise to caution again excessive use of mechanical "gadgets." The dairyman who has a tight schedule cannot afford to take time to make frequent repairs

Fig. 35. A completely mechanized arrangement for feeding silage to dairy cattle. (Courtesy Babson Bros. Co.)

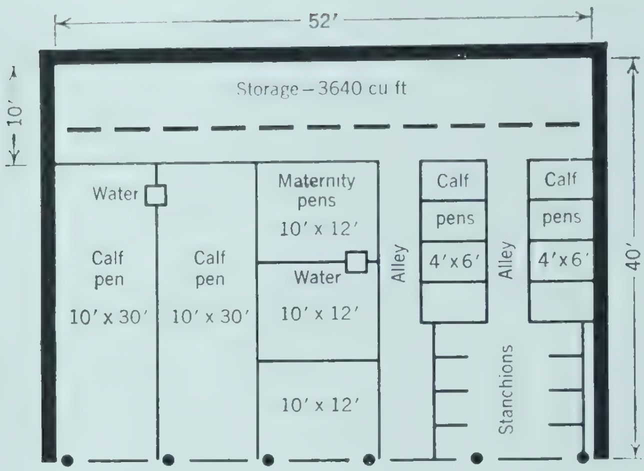


Fig. 36. A convenient shed for calf pens and maternity stalls for a 75-cow herd. (Courtesy Babson Bros. Co.)

or adjustments. Equipment on the dairy farm must be as dependable and foolproof as possible.

In most areas provision should be made for green crop feeding. Most arrangements for silage feeding can be used for chopped green forage. The principal consideration is to provide for the convenient access of wagons and trucks to silage mangers or mechanical feeders.

Calf Pens and Maternity Stalls. Young calves can be housed satisfactorily in an open shed even in cold climates if they are provided

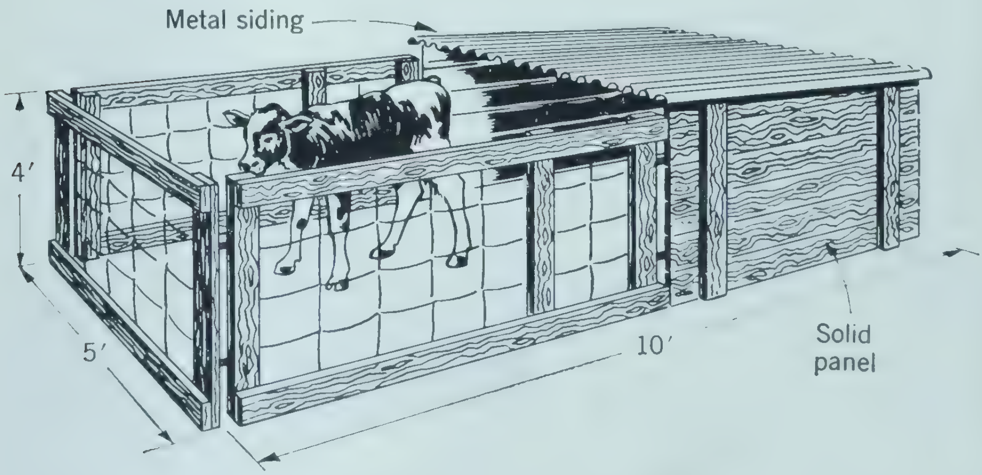


Fig. 37. A calf pen such as this can be used to advantage in milder climates. (Courtesy Babson Bros. Co.)

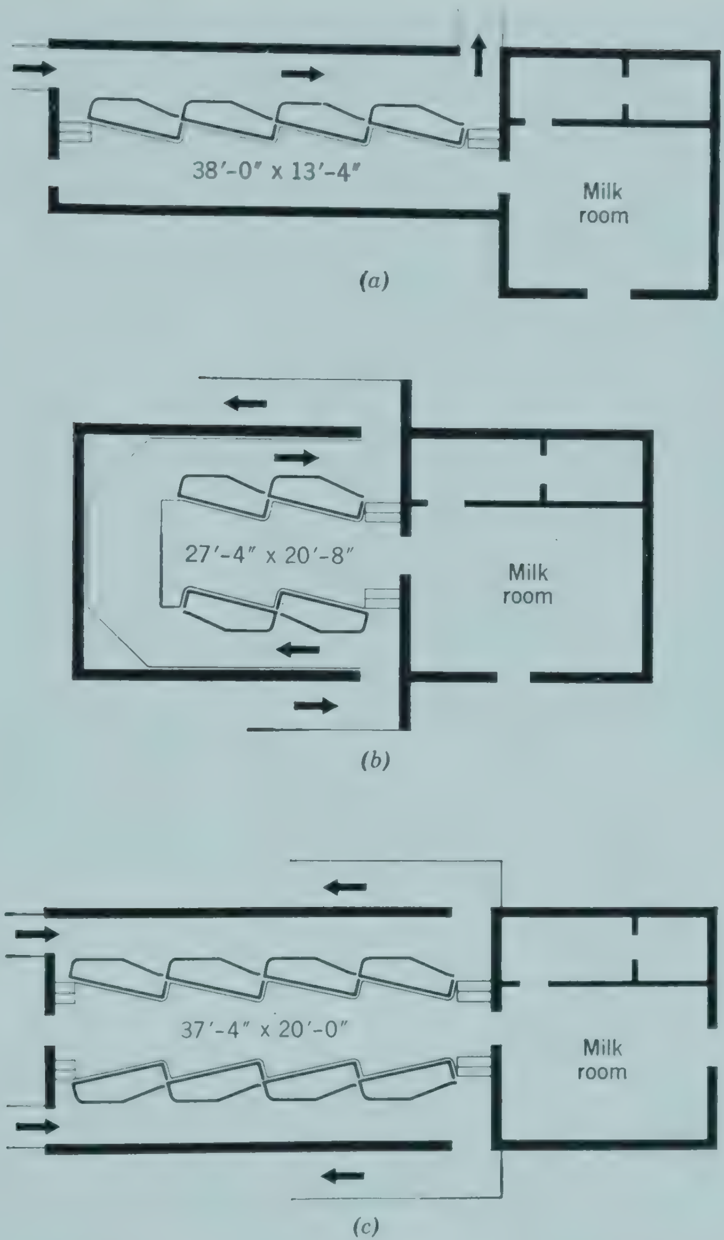


Fig. 38. Typical milking parlor arrangements: (a) single row, four-stall, one man milking parlor for use with pipeline equipment; (b) U-type, four-stall, one man milking parlor for use with pipeline equipment; (c) double row, eight-stall, two-man operation with pipeline equipment for larger herds. (Courtesy Babson Bros. Co.)

Fig. 39. An illustration of an automatic feeding device. (Courtesy Babson Bros. Co.)

with dry bedding and protected from drafts. An open shed is ideal for older heifers and dry cows. A convenient loose housing shed arrangement which will be adequate for use with a 75-cow herd is shown in Fig. 36. In warmer climates such structures may be unnecessary. Young calves frequently are kept in movable pens similar to that shown in Fig. 37. Losses due to disease and parasites are minimized by moving the pens to clean areas periodically.

Milking Facilities. Loose housing of dairy cows requires the use of a milking parlor or a conventional stall barn for housing the animals during the milking process. In the more modern operations, a milking parlor generally is used. The type, size, and arrangement may vary widely depending on the several factors listed below.

1. Size of herd.
2. Number of persons to do milking.
3. Resources that can be invested.
4. Local sanitary regulations.

In general, milking facilities will include the following:

1. A milking room.
2. A milk room with space for a bulk tank.
3. Room for utensil washing and storage, vacuum pump, and heating facilities. (Sometimes combined with milk room.)
4. Concentrate storage facilities.

Milk-handling equipment will not be discussed further. The milking room is generally arranged so that the cows will stand on a raised platform in order that they can be milked without the operator stooping. Milk generally is carried automatically through a sanitary pipeline to a bulk tank. Stalls are arranged in various ways as shown in Fig. 38. Many other arrangements are in general use.

Fig. 40. This built-in elevator carries the concentrate mixture to an overhead storage bin from which it is removed by the automatic feeder. (Courtesy Babson Bros. Co.)

The size of the herd and the preference of the dairyman are the principal factors in selecting the type to use on a particular farm.

Concentrates generally are fed in the milking room. In some cases the feed is taken from a box or feed truck by hand and put into the feed box. It may be stored in an adjoining room in bags or in a bulk bin overhead. Recently, feed metering devices for milking parlors have been put on the market. A small bin above each feed box is filled mechanically from an overhead bin. Each cow is given the proper amount of feed by the movement of a lever. An example of this type of feeder is shown in Fig. 39. A built-in elevator for filling the overhead bin is shown in Fig. 40. Because the milking process requires only a relatively short period of time, trouble is sometimes experienced in getting cows to clean up all of their concentrate before milking is completed. This problem frequently can be remedied by using pelleted feed or by adding about 1½ pt of water per pound of concentrate. This practice has been reported to increase the rate of consumption very markedly.

QUESTIONS

1. What are the trends in dairy cattle housing?
2. How do housing needs vary in different parts of the country?
3. What are the advantages and disadvantages of one and two story stall dairy barns?
4. How can stall barns be used to advantage when the dairy herd is increased in size?
5. What are the most important considerations in selecting a location for a dairy barn?
6. What temperature should be maintained in the stall dairy barn during winter months?
7. List the advantages of loose housing for dairy cattle.
8. What are the disadvantages of loose housing for dairy cattle?
9. What facilities must be included in a loose housing layout for northern climates?
10. What facilities are needed in a loose housing layout for warm climates?
11. What are the essentials of a good loafing barn for cold climates?
12. What are the essentials of a good feeding area for cold climates?
13. What is needed in the way of feeding and loafing areas for cows maintained in warm climates?
14. What arrangements are being used in your area to reduce the labor cost of feeding dairy cattle?
15. What arrangements mentioned in this chapter are not suited to your area? Why?

16. What should a dairyman provide in the way of housing for calves, heifers, dry cows and maternity pens for a 100-cow milking herd?
17. How are calves sometimes housed in warm climates? What are the advantages of this system?
18. What is needed in the way of milking facilities for a 50-cow herd?
19. Plan a complete loose-housing layout for a 75-cow herd to be maintained in your community.

REFERENCES

Thayer Cleaver, Harold J. Thompson, and Robert G. Yeck: "Stall Barns for Dairy Cattle," *U.S.D.A. Agriculture Information Bull. 123*, 1954.

Thayer Cleaver and Robert G. Yeck: "Loose Housing for Dairy Cattle," *U.S.D.A. Agriculture Information Bull. 98*, 1953.

"The Way Cows Will Be Milked On Your Farm 'Tomorrow,'" Babson Bros. Dairy Research Service, Babson Bros. Co., Chicago, 1959.

CHAPTER **10**

Herd Records

The operation of a modern dairy farm requires the keeping of records just like any other progressive business. Records are particularly important as far as the herd is concerned. If properly used, they can serve as the basis for developing a profitable enterprise. Lack of records can result in mediocre success or business failure. The various types of herd records needed will be discussed.

Identification of Cattle. Herd records depend first of all on the positive identification of each and every animal in the herd. In the case of registered animals, each breed association has very specific requirements. With Ayrshire, Guernsey, and Holstein cattle, a sketch of coat markings of both sides of the body and the face must be shown on the application for registration or photographs of the same included with it. In the case of the Jersey and Brown Swiss breeds, animals must be given a tattoo number in the ear.

Because tattoos are hard to read and the use of coat markings depends primarily on memory, the day to day identification of cows in larger herds requires that other methods be used. This is true in the case of both purebreds and grades. The most common method of identification is the ear tag, which is available in the metal band and can be purchased with a number on it or numbered on the farm, and the numbered plastic disc which is attached to the ear by means of a small metal ring. Other methods used are the horn chain, and the neck chain, and the neck strap, all of which carry numbered metal or plastic plates. These tags are read very easily.

When each cow is kept in a particular stall in the barn, it also is a good practice to have a name or number plate above each stall. Such a plate can show, in addition to the name or number, the freshening date, production records, etc.

In smaller herds, the name of the cow usually is used instead of a number. In cases where all animals are home bred, breeders have used the name to indicate the year in which animals were born. For example, the animals born in the year in which the system was put into effect would have names beginning with "A," the next year with "B," etc. In larger herds, however, the daily use of names is cumbersome, particularly where identification of each animal must be checked at each feeding and milking. It also is much easier to write numbers than names when keeping records.

Breeding Records. The ideal calving interval for the dairy cow is 12 to 13 months. In other words, it is desirable to have every cow in the herd freshen every 12 months or slightly over. In order to approach this goal as closely as possible, dates of freshening, heat periods, breeding, abnormal conditions, etc., must be recorded. Such records serve the following purposes:

1. Indicate when to start breeding.
2. Aid in feeding program.
3. Indicate breeding efficiency.
4. May suggest disease problems or need for veterinary service.
5. May suggest infertility of bull being used.
6. Indicate when to turn cow dry.
7. Indicate approximate date of calving.
8. Show parentage and disposal of calf.

An example of a good breeding record form is given in Fig. 41. By using such a form a dairyman has a complete reproductive history of each cow in the herd. He knows when she is due to be bred, when she is bred, the sire used, and when she is due to freshen. If the cow does not come into heat or does not conceive in the normal period of time, the dairyman has the information readily available. Breeding normally should be started 60 to 90 days after calving. This timing gives the fresh cow a better chance to recover from any uterine infection and generally results in conception with fewer services. With such records a breeding problem usually can be detected before it has done serious damage and the veterinarian can identify the cause of the problem much more readily. The cow can

DAIRY BREEDING RECORD

Name or Ear Tag	Date Fresh	Heat Dates 1st	Heat Dates 2nd	Date Bred	Bull	Days Since Service	Date Rebred	Bull	Days Since Service	Date Rebred	Bull	Days Since Service	Date Rebred	Bull	Due to Calve	Calved	Sex	Remarks

1. BREED COWS FROM MIDDLE TO END OF HEAT
2. WAIT AT LEAST 60 DAYS AFTER FRESHENING BEFORE BREEDING
3. LEAVE MONEY AND REGISTRATION CERTIFICATE FOR TECHNICIAN
4. MARK COW TO BE INSEMINATED

For further information contact the New Hampshire-Vermont Breeding Association, at CApitol 4-1471 or P. O. Box 350, Concord, New Hampshire.

Fig. 41. An example of a good breeding record form. (Courtesy New Hampshire-Vermont Breeding Assoc.)

be turned dry on the proper date so that there will not be an excessively long wasteful dry period or a period so short that the cow does not get adequate rest. A dry period of 60 days is considered ideal. A breeder of purebreds has to maintain accurate breeding records for purposes of registering animals and writing pedigrees. In fact, he is morally obligated to do so.

Production Testing. There are several types of production testing. The type that should be used depends on various factors such as the following:

1. Purebreds vs. grades.
2. Sale of breeding stock.
3. Level of production of herd.
4. Type of milk market.
5. Size of herd.
6. Financial resources of dairyman.
7. Interest and ability of dairyman.

Production testing is easily justified. It is important that every cow in the herd make a reasonable profit. Let us assume that in a certain herd where production testing is not being practiced, 6 cows are low producers and are losing money. In this same herd, 6 high producers are making the same sum that the low producers are losing. Thus the 6 poor cows cancel out the profits from keeping the 6 good cows and the dairyman would be just as well off with 12 fewer cows. If the 6 poor cows were eliminated, however, he would be much better off. This represents a waste of much labor, feed, and housing which could be used to care for a similar number of profitable cows.

The owner of purebred cattle should keep more extensive records than the breeder of grades. This would be particularly true for the breeder of purebreds who has a high-producing herd and derives much of his income from the sale of breeding stock. Such a dairyman probably should do official testing and maintain accurate and complete production records for all animals for several generations. A dairyman who keeps cows for purposes of milk production only does not need such extensive records. He needs to know which animals are profitable to keep and which ones should be culled from the herd. Such information also is useful in carrying out herd improvement through breeding and helps in selling grade cows at improved prices. Production testing is divided into three categories.

PRIVATE PRODUCTION RECORDS. These records can be kept by any

herd owner who is interested enough. A few dairymen weigh and record the milk produced by each cow at every milking, and still fewer test it monthly for butterfat. Other dairymen weigh each cow's production 2 or 3 days per month, compute the average, and multiply it by the number of days in the month to get the monthly total. Monthly totals are added to get lactation totals. Milk record sheets, such as shown in Fig. 42 can be obtained without cost from various feed manufacturers or purchased from dairy supply houses.

Most dairymen who desire to carry on production testing, however, find that it is very difficult to do the work themselves. Even though their intentions are good, the testing usually is discontinued after a few months. Besides, records obtained in this way have little value except to the dairyman himself. Thus dairymen who wish to do production testing generally prefer to hire a disinterested person to do it, so that the work will be carried out on schedule and, also, so that the results will be accepted by others.

OFFICIAL TESTING. Official testing includes those programs which are sponsored by the various breed associations for their own purebred cattle. Official testing is divided into *Advanced Registry* (A.R.) and *Herd Improvement Registry* (H.I.R.). The testing rules are made by each breed association, but have been standardized to a considerable extent by the *Unified Rules for Official Testing* through the efforts of the Purebred Dairy Cattle Association and the American Dairy Science Association. The program for all breeds is supervised in each state by the Superintendent of Official Testing at the land-grant college. The actual testing is carried out by a supervisor who is paid by the land-grant college from fees collected from participating dairymen.

Advanced Registry testing as it is known in the Guernsey and Holstein breeds (Register of Merit testing in the Jersey breed and Register of Production in the Brown Swiss breed) is carried out on selected cows in the herd. Milk weights must be kept for each milking, except for Jerseys, and the milk is tested for butterfat one day per month, except for Guernsey where a bimonthly test is permitted. Records are classified according to age of cow at time of calving, frequency of milking, and length of lactation. Because the rules vary slightly among the different breeds, one should consult the Unified Rules for Official Testing for specific details.

Herd Improvement Registry testing, or herd test as it is commonly known, must be carried out on all purebred cattle of the particular breed in the herd with a very few exceptions. Milk and butterfat are calculated from one day's production each month, except with

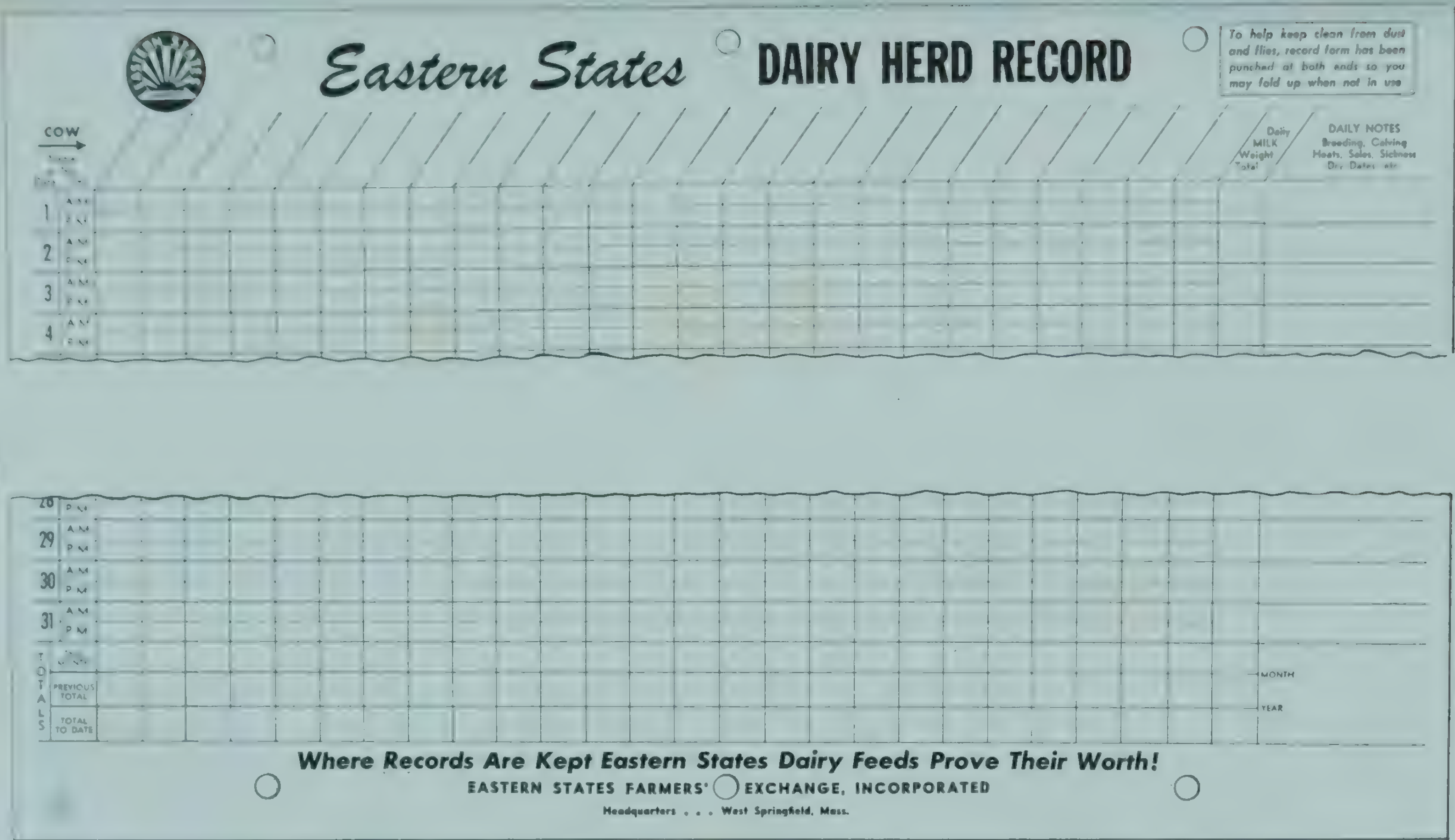


Fig. 42. A good form for recording daily milk weights for a calendar month. (Courtesy Eastern States Farmers' Exchange.)

Guernseys where bimonthly testing is permitted. With most breeds individual cow records and herd averages are calculated by the breed association on a testing year basis. The Guernsey breed calculates production on a lactation basis and does not provide a yearly average.

Because Advanced Registry testing is based on the making of records on selected cows under more or less unusually favorable conditions, it has been replaced gradually by H.I.R. testing. Most breeders have come to the realization that a sound breeding program depends on the testing of *all* cows in the herd under regular herd conditions. For this reason relatively few cows are now being tested under A.R. rules, and the Ayrshire breed abandoned the program entirely several years ago.

THE NATIONAL COOPERATIVE DAIRY HERD IMPROVEMENT PROGRAM. This program is supervised at the national level by the Dairy Cattle Research Branch, Agricultural Research Service and the Federal Extension Service, U.S. Department of Agriculture. On the state basis, supervision is provided by the Cooperative Extension Service. The actual testing is carried out by a supervisor employed by the local Cooperative Dairy Herd Improvement Association. The association usually is organized on a county basis and the county agricultural agent serves in an advisory capacity. This program includes the Standard Dairy Herd Improvement Association, Owner-Sampler, and Weigh-A-Day-A-Month plans.

The Standard Dairy Herd Improvement Association operates by having the supervisor visit each farm once a month to weigh and test for butterfat one day's milk production from each cow. He also records calving, breeding, and drying off dates and concentrate and forage consumption. Under the manual system this data is used by the supervisor to calculate monthly milk and fat production, amounts of feed consumed, the cost of feed, and the return over feed cost. A running total is kept for the testing year.

During the past few years electronic data computers have been put to use to handle the computation and summarization required with this program. The supervisor records the amount of milk produced on the day of the test, the butterfat percentage, the amount and quality of each feed consumed, the prices of milk and feed, and other essential data on a form such as shown in Fig. 43. This sheet then is sent to a state or regional data processing center and complete monthly totals for each cow, the herd, and a running summary are calculated and recorded automatically on a form such as Fig. 44, which is sent to the herd owner.

DAIRY HERD I

HERD CODE		
ST	CO	HERD NO
12	16	0103
TYPE OF RECORD		
		DHIA

ROCKCO COUNTY HOME

EPPING NH 6 13

HERD DATA	AV BODY CWT	NUMBER COWS	% DAYS IN MILK	% DAYS MILKED 3X	MILK	% TEST	FAT	CONCENTRATES FED		SUCCULENTS FED		DRY & ROUGHAGE FED	
					POUNDS		POUNDS	LB	% NE	LB	% NE	LB	% NE
DAILY AVERAGE PER COW THIS MONTH		39	98		39.7	4.0	1.6	10	26	90	43	20	31
					CWT		10 LB	CWT		CWT		CWT	
12-MO HERD TOTALS					5807		2357	1948		11380		3074	
					POUNDS		POUNDS	CWT	% NE	CWT	% NE	CWT	% NE
12 MO HERD AVERAGE	13	42 1	87		13793	4.1	560	46	34	270	35	73	31

REGISTRATION OR EARTAG NUMBER OF COW	BREED ✓	TEST DAY DATA: STATUS CODE ✓	DATE OF CHANGE MO	DATE OF CHANGE DAY	DAILY MILK WT (LB)	% TEST	CONCENTRATES LB FED	CONCENTRATES LB INDICATED	BARN NAME	COW INDEX NUMBER	CURRENT TEST PERIC: DAYS IN MILK ✓	MILK LB
2681903	3	1			250	3.4	6		RVALE	4	30	750
3125301	3	1			660	3.9	16	12	FAY	7	30	1980
3264476	3	1			804	3.6	20	17	OCASS	9	30	2410
3264475	3	1			290	3.5	7		ROSEBD	10	30	870
3351735	3	4	2	5	439	3.9	11	2	VIOLET	12	30	1320
3351738	3	1			265	4.1	7		TIDY	13	30	800
3351736	3	4	2	22	330	4.4	8		REBECA	14	30	990
3380226	3	1			647	3.1	16	8	LENIA	15	30	1940
3486578	3	4	2	21	426	4.3	10	3	MATTIE	16	30	1280
3486581	3	2	5	10					RUBY	17		
		2	5	10	534	4.6	13	11		17	41	2190
3486588	3	1			395	4.0	10	1	PEACH	18	30	1190
3511879	3	1			516	4.3	13	6	DOT	20	30	1550
3610726	3	3							AVA	24		
3698904	3	4	2	22	341	4.2	9		AILEEN	27	30	1020
3698905	3	1			470	3.0	12	7	ALANE	29	30	1410
3698906	3	1			339	3.3	8		ALDA	30	30	1020
3698911	3	4	1	15	255	4.1	6		AGATHA	32	30	770
3698912	3	1			615	4.3	15	14	ASTRID	33	30	1850
3782580	3	4	2	16	534	3.4	8	6	AMBER	34	30	1600
3763384	3	4	1	15	162	6.1	4		ADONCA	35	30	490

48

Fig. 44. Form used by electronic data processing center for repc

DHIA-200 (`-57)

MPROVEMENT RECORD

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE -
DAIRY HUSBANDRY RESEARCH BRANCH AND
STATE AGRICULTURAL EXTENSION SERVICES COOPERATING

ATE PROCESSED			CENTERING DAY	DATE TESTED		DAYS FROM CENTERING	TEST PERIOD FROM		TEST PERIOD TO	
	DAY	YR.		MO	DAY		MO	DAY	MO	DAY
5	17	58	8	6	10		5	24	6	22

PASTURE		FEEDING INDEX	RATE OF ROUGHAGE FEEDING	VALUE OF PRODUCT	COST CONCENTRATES	FEED COST	INCOME OVER FEED COST	FEED COST PER CWT MILK	WORKERS	PRODUCTION/WORKER MILK	PRODUCTION/WORKER [illegible]	MILK PER ACRE
	% NE			$	$	$	$					
			3.6	1.98	0.33	1.16	0.82					
10 DAYS				$10	$10	$10	$10					
				3414	658	1672	1742					
DAYS	% NE			$	$	$	$	$	NUMBER	1000 LB	$100	CWT
		133	3.3	811	156	397	414	2.88	04.8	121	36	26

LACTATION TO DATE

)D FAT LB	AGE AT CALVING (MOS)	BODY CWT	NUMBER DAYS DRY	NUMBER DAYS CARRIED CALF 5/	NUMBER DAYS MILKED 3X	NUMBER DAYS IN MILK 6/	MILK POUNDS	% TEST	FAT POUNDS	VALUE OF PRODUCT $	INCOME OVER FEED COST $ 7/	COND AFF REC 3/
26	132	14	78			468*	24420	3.5	854	1437	798	
77	105	13	65			135*	9360	3.9	361	509	314	
87	93	14	82			114*	8950	4.0	360	495	316	
30	88	14	57			263*	13450	3.8	505	814	463	
51	82	14	60	138		218	11810	4.2	492	735	437	
33	80	13	58			280*	13420	4.5	601	871	536	
44	79	14	65	121		309	16980	4.4	748	1082	667	
60	83	14	90			135*	9930	3.4	341	515	307	
55	71	13	78	122		214	12090	4.2	502	755	464	
	58	12	65	460		482	19640	4.6	909	1325	802	☐
101	76	12	65			41	2190	4.6	101	119	69	
48	66	14	51			299*	15390	4.6	711	997	607	
67	71	14	83			115*	7160	4.2	301	409	236	
	54	12	53			419	21980	4.0	881	1285	755	
43	57	14	57	121		263	11220	4.3	487	713	390	
42	57	12	71			212*	13360	4.6	608	914	282	
34	57	13	65			227*	10870	3.7	397	647	372	
32	53	14	65	159		272	11480	3.9	446	699	320	
80	61	12	120			76*	4720	4.6	216	274	173	
54	52	13	72	127		212	14070	3.6	512	877	527	
30	42	12	54	159		461	16220	4.9	787	1039	571	

EXPLANATORY NOTES

1/ Breed Code:
1. Ayrshire
2. Guernsey
3. Holstein
4. Jersey
5. Brown Swiss
6. Milking Shorthorn
7. Red Dane
8. Other

2/ STATUS CODE:
1. In milk
2. Calved
3. Dry
4. Bred
5. Left Herd
7. Entered Herd
8. Aborted

3/ Conditions Affecting Record:
1. Estimated
2. Incomplete; Sold
3. Incomplete; Died
4. Injury
5. Mastitis
6. Ketosis
7. Other Sickness
8. Abortion
9. Nurse Cow

305 Day Lactation

☐ Complete Lactation

4/ * Milked 3x this test period

5/ * Cows need to be dried off at 220 days of pregnancy in order to have a 60-day dry period

6/ * Cow in milk more than 60 days. Breed cows 60 to 90 days after freshening for normal (12 to 13 month) calving interval.

7/ *Feed record not valid. Did not start at calving

…rting to herd owner. (Courtesy Dairy Cattle Research Branch, U.S.D.A.)

NYDHIC 57

D.H.I.A.

New York Dairy Herd Improvement Cooperative, Inc.

LIFETIME RECORD OF INDIVIDUAL COW

Index No. 9

0 S

Registration Name Rocko Ormsby Cass

Registration Number 3264476

Barn Name O Cass

Tattoo Number

Eartag Number CV1781

Breed Reg. Hol.

Birth Date 5/3 1950

Progeny of Artif. Insem.? X

Secondary Eartag

Sire Greenwood Ormsby Della

Eartag or Reg. No. 772380

Dam Rocko Miss Jane

Index Number 2

Eartag or Reg. No. 2639864

RECORD OF TEST DAY MILK WEIGHTS

Lact No	Date Fresh MO	DAY	YR	Month of Lactation 1	2	3	4	5	6	7	8	9	10	305 Day Mature Equivalent Milk	B F
1	10	19	52	48^0	41^5	39^4	44^0	38^3	36^6	31^5	28^0	32^7	29^5	15688	556
2	1	9	54	58^0	67^2	54^9	55^3	46^9	39^5	35^0	11^9	11^7		13087	461
3	1	8	55	56^1	65^3	68^0	68^7	62^3	54^8	44^8	42^5	45^6	36^4	16727	586
4	2	5	56	63^6	69^0	76^0	69^2	64^7	58^0	58^3	51^7	37^4	5^2	15928	596
5	2	12	57	94^3	98^0	92^5	84^8	80^5	67^7	56^5	49^2	12^4		20140	705
6	2	26	58	67^0	79^5	84^3	80^4	70^4							
7															
8															
9															
10															

LACTATION PRODUCTION SUMMARY

Lact No	Type of Record	Age at Freshening (Months)	Weight When Fresh	Days Dry Before Calving	Days Carried Calf	Days Milked 3X	Days in Milk	First 305 Days MILK	%	B.F	Lactation Total / Lifetime Total MILK	B.F	Income Above Feed Cost
1	DHIA	29	1160		210		374	11300	36	403	12550	445	412
2	"	44	1281	68	191		291		35		12550 11790	445 415	373
3	"	56	1320	89	223		340	16240	35	569	24340 16970	860 594	558
4	"	69	1365	60	198		288		37		41310 15770	1454 590	555
5	"	81	1398	84	226		297		35		57080 20140	2044 705	671
6	"	93	1425	57							77220	2749	
7													
8													
9													
10													

Fig. 45. Lifetime record of individual cow. (Courtesy New York Dairy Herd Improvement Cooperative Association.)

Index No. 9

Barn Name O Cass

CALVING RECORD

Lact No	Date of Calving MO	DAY	YR	Calf's Name and Eartag No.	Sex of Calf	Sire of Calf	Calf's Index No	Disposal of Calf
1	10	19	52	Rocko Nero	M	Hero		Sold E. Waterman
2	1	9	54	Rocko Chieftain Ormsby	M	R. Chieftain		" A. Laborate
3	1	8	55	" Carl Betty 3961783	F	H. O. Carl	52	
4	2	5	56	" Conqueror Dahlia 4187010	F	U.N.H.M Conqueror		
5	2	12	57	" Squire Cass 1317967	M	Squire		
6	2	26	58	" Burke Fanny	F	R. B. Valiant		
7								
8								
9								
10								

HEALTH AND VETERINARY RECORD
To be Maintained by Herd Owner

Dates			Factors Affecting Breeding Efficiency				Factors Affecting Production					Other Sickness or Injury	Treatment	Cost
MO.	DAY	YR.	Brucellosis Test Results	Vibriosis Test Results	Cystic Ovaries	Retained Placenta	Milk Fever	Ketosis	Abortion	Foot Trouble	Mastitis—Extent of Inf		BRUCELLOSIS VACCINATED 19	
					CHECK APPROPRIATE COLUMN									

Fig. 46. Calving and health and veterinary records. (Courtesy New York Dairy Herd Improvement Cooperative Association.)

The form which is returned to the herd owner provides information for the test day, the current test period, and the lactation to date for each cow. In addition, it gives the weight of concentrate which each cow needs. When the supervisor makes his next visit to the farm, he copies from the Dairy Herd Improvement Record on to the appropriate Lifetime Record of Individual Cow, as shown in Fig. 45, the monthly test-day weights and completed 305-day lactation production summaries as they become available. On the back of this form, as shown in Fig. 46, are a Calving Record and a Health and Veterinary Record. The latter is used by the herd owner as a permanent record for information usually recorded previously on a form kept at the barn.

Electronically processed data are particularly desirable because they are accurate and also because they provide considerable information not furnished by the older D.H.I.A. program. Particularly important in this respect are average yearly milk production per man and per acre, feed cost per hundredweight of milk, and the per cent of net energy intake obtained from each type of feed. This type of information gives the herd owner a sound basis for measuring the efficiency of his dairy enterprise.

The processing of testing data by electronic data computers under the D.H.I.A. program is becoming widely accepted, and eventually all such data probably will be processed in this way. Some of the breed associations are now willing to accept such records under certain conditions, and it is predicted that eventually all production testing will be carried out on this basis with records of purebreds being sent to the appropriate breed association. This system will relieve the breed associations of the heavy expense of maintaining expensive computing equipment for summarizing production records and will standardize testing procedures.

When a 305-day record is completed it is calculated automatically by the electronic data computer and punched on a special card as shown in Fig. 47. Similar records are calculated manually under the older system. These records are sent to the U.S. Department of Agriculture, where they are used for various research purposes. Of particular interest is their use in calculating state and national averages for milk and butterfat production and for proving bulls under the National Proved Sire Program. A proved sire record is a tabulation that shows the average milk and butterfat production of five or more unselected daughters of a sire and their dams and the amount of the average increase or decrease by the daughters.

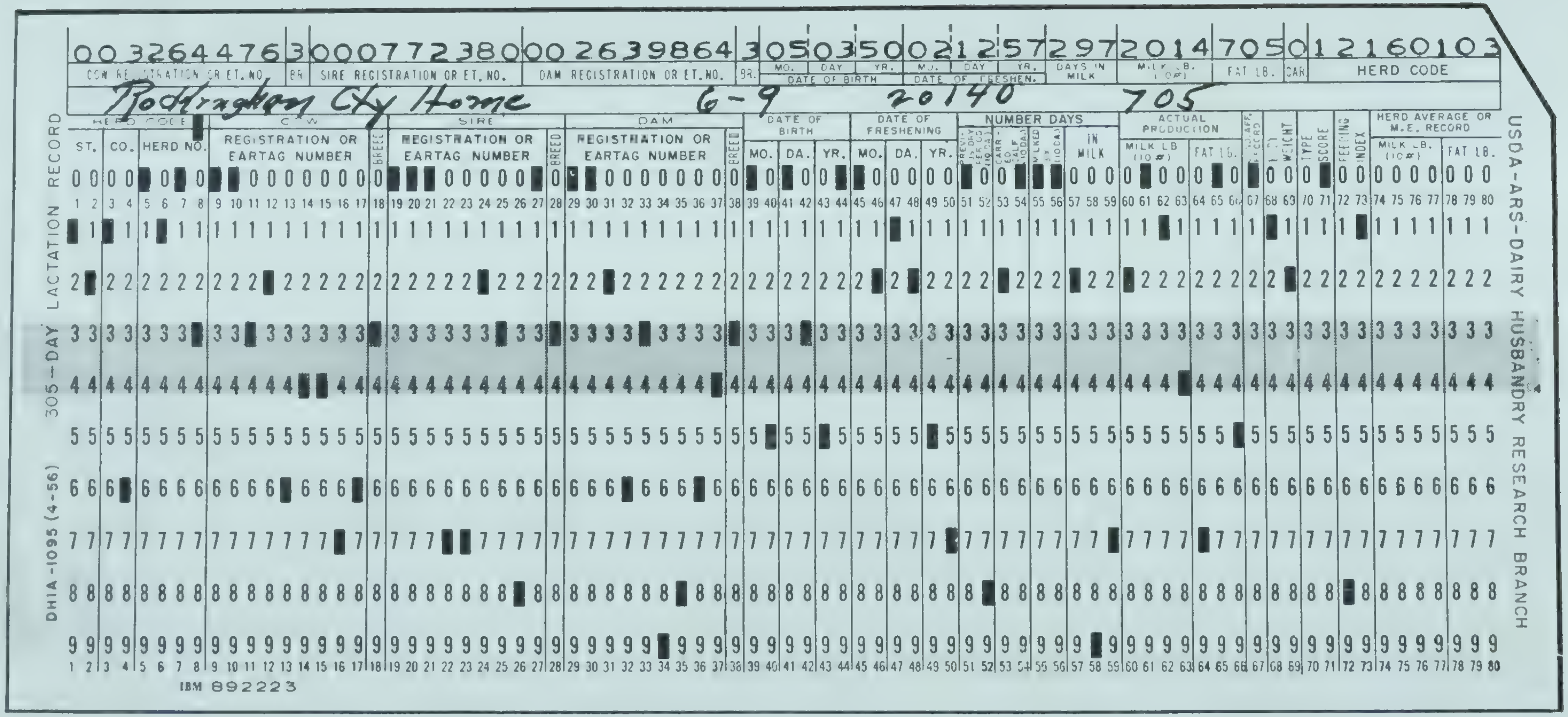


Fig. 47. A punch card for a 305-day lactation period. (Courtesy Dairy Cattle Research Branch, U.S.D.A.)

DHIA-OS-2
(6-56)

OWNER-SAMPLER HERD RECORD

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
DAIRY HUSBANDRY RESEARCH BRANCH AND
STATE AGRICULTURAL EXTENSION SERVICES COOPERATING

COPY FOR
HERD RECORD BOOK

HERD CODE ______ MONTHLY REPORT FOR ______ 19__

OWNER ______ CENTERING DATE ______

ADDRESS ______ TESTING YEAR BEGAN ______, 19__

WORK SHEET FOR MONTH OF:

SAMPLE NUMBER	NAME OF COW	REMARKS: DATE FRESH, DRY, BOUGHT, ETC.	GRAIN FED DAILY LB.	DAILY MILK (Lb.)		TOTAL DAY'S MILK	THIS MONTH				TOTAL FOR YEAR OR SINCE FRESH			Grain recommended daily lb.
				P.M.	A.M.		DAYS IN MILK	MILK LB.	TEST %	FAT LB.	DAYS	MILK LB.	FAT LB.	

HERD SUMMARY	COW—MONTHS ON TEST	MILK LB.	TEST %	FAT LB.	VALUE OF PRODUCT (DOLLARS)	TOTAL COST OF FEED (DOLLARS)	INCOME OVER FEED COST (DOLLARS)
TOTALS BROUGHT FORWARD							
TOTAL FOR MONTH							
TOTAL TO DATE							
AVERAGE FOR MONTH							
AVERAGE FOR YEAR							

★ U. S. GOVERNMENT PRINTING OFFICE 1956—390317

Fig. 48. The Owner-Sampler herd record. (Courtesy Dairy Cattle Research Branch, U.S.D.A.)

DHIA-WAD-3
(6-56)

WEIGH-A-DAY-A-MONTH HERD RECORD
UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
DAIRY HUSBANDRY RESEARCH BRANCH AND
STATE AGRICULTURAL EXTENSION SERVICES COOPERATING

COPY FOR
HERD RECORD BOOK

HERD CODE ______

OWNER ______ MONTHLY REPORT FOR ______ 19__

ADDRESS ______ MILK RECORDING YEAR BEGAN ______ 19__

FEED COST	MILK PRICE	TEST %

WEIGH MILK 15TH DAY OF EACH MONTH

BARN NAME OF COW	THIS MONTH			TOTAL FOR YEAR OR SINCE FRESH		COW INDEX NUMBER	WORK SHEET FOR MONTH OF:		
	DAYS IN MILK	DAILY LB.	TOTAL LB.	DAYS IN MILK	MILK LB.		DAILY MILK (LB.)		REMARKS: DATE FRESH, BOUGHT, SOLD, DIED, ETC.
							A.M.	P.M.	

HERD SUMMARY	COW—MONTHS ON TEST	MILK LB.	TEST %	FAT LB.	VALUE OF PRODUCT (DOLLARS)	TOTAL COST OF FEED (DOLLARS)	INCOME OVER FEED COST (DOLLARS)
1. TOTALS BROUGHT FORWARD							
2. TOTAL FOR MONTH							
3. TOTAL TO DATE							
4. AVERAGE FOR MONTH (PER COW)							
5. AVERAGE FOR YEAR							

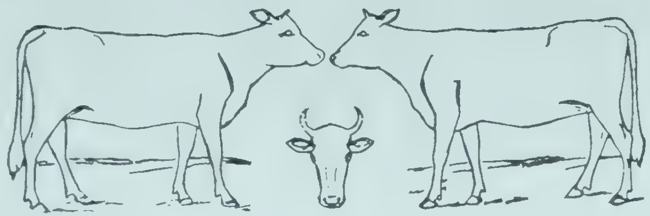
Fig. 49. The Weigh-A-Day-A-Month herd record. (Courtesy Dairy Cattle Research Branch, U.S.D.A.)

The Owner-Sampler plan is a modified version of D.H.I.A. Once a month the herd owner weighs and samples the milk from each cow for two consecutive milkings. Milk weights for each cow, calving and going-dry dates, and other pertinent data are recorded on a special form, as shown in Fig. 48. The recording of feed consumption weights is optional. The supervisor picks up the milk samples and the form. He tests the milk for butterfat and calculates production and feed consumption in the usual manner. Owner-Sampler records are unofficial because the weighing and sampling are not done by a disinterested person. They are used, therefore, only by the herd owner for herd improvement purposes. This is a low-cost program of testing which frequently leads to enrollment in the D.H.I.A. program.

The Weigh-A-Day-A-Month plan is a still more economical form of testing. It is particularly adapted to small herds. The herd owner weighs both milkings for each cow on the fifteenth of each month and enters the figures on the form shown in Fig. 49. He also records dates of freshening, going dry, bought, sold, and died. Butterfat samples are not taken, but average butterfat production for the herd is calculated from the monthly milk plant test. Herd feed records may be included. The dairyman sends the forms to the office of the county agricultural agent or to a central computing center where the records are calculated and mailed back to him. These results are unofficial and are used only by the dairyman.

Herdbooks. Many dairymen find it desirable to use a herdbook to maintain the necessary records on their cattle. Such books vary from complex expensive types to inexpensive notebooks. A substantial and fairly complete herdbook is particularly useful for the breeder of purebred cattle. It also can be used to advantage by the breeders of grades. Some breeders carry a pocket size herdbook, which is particularly useful in discussing the records of animals with prospective purchasers.

A good herdbook should provide for recording such information as the name and registration number of the animal, names and numbers of sire and dam, date of birth, breeder, breeding record including name, number, sire, and disposition of each offspring, monthly production of milk and butterfat, 305-day and total lactation records and the age at which the records were made, a health record form, and a three-generation pedigree. Such records when kept over a period of many years are of great help in herd improvement. A page from a good herdbook is shown in Fig. 50.



Name and Number ______

Date of Birth ______
Breeder ______
Owner ______
Date ______
Compiled by ______

PROGENY RECORD OF ______

Date Served	Name and Number of Bull	Due to Calve	Date Calved	Sex	Name and Number of Calf	Remarks

PRODUCTION RECORD

YEAR																					
Month	Milk lbs.	Butterfat		Milk lbs.	Butterfat		Milk lbs.	Butterfat		Milk lbs.	Butterfat		Milk lbs.	Butterfat		Milk lbs.	Butterfat		Milk lbs.	Butterfat	
		%	lbs.		%	lbs.		%	lbs.		%	lbs.		%	lbs.		%	lbs.		%	lbs.
Totals																					

Fig. 50. Front and back of sheet used in herd book.

QUESTIONS

1. Why is it important that all dairy cattle carry means of identification?
2. What methods of identification are used and what are the advantages of each?
3. What purposes do good breeding records serve?
4. How long after freshening should breeding start? Why?
5. What is the purpose of production testing?
6. What factors determine the most desirable type of production testing?
7. What is meant by official testing?
8. How is official testing supervised?
9. What are the differences between Advanced Registry and Herd Improvement Registry testing?
10. Why is H.I.R. testing gradually replacing A.R. testing?
11. How is the Dairy Herd Improvement Association program supervised?
12. What differences are there between the kind of records kept under H.I.R. and D.H.I.A.?
13. What are the advantages of using electronic computers in the D.H.I.A. program?
14. What is the Owner-Sampler plan and under what conditions is it most useful?
15. What is the Weigh-A-Day-A-Month plan and under what conditions is it most useful?
16. When the D.H.I.A. supervisor visited the farm, cow A produced 75 lb of milk testing 3.7 per cent. Calculate the milk and butterfat for the testing month.
17. During a certain lactation cow B produced 13,786 lb of milk and 579 lb of butterfat. What was the per cent of butterfat for the lactation total?
18. The cow B in number 17 above was in production 10 months and dry 2 months. During the year she consumed 2,950 lb of a 16 per cent protein concentrate mixture, 9.75 tons of corn silage, and 1.75 tons of mixed hay. Using average prices for feed and milk in your community, calculate returns over feed cost.

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CHAPTER 11

Maintaining a Healthy Herd

Disease and a profitable dairy herd are rarely found on the same farm. Diseases of various types cost the dairymen of the United States many millions of dollars a year in decreased milk production, slower growth, abnormal milk, condemned carcasses, dead animals, and veterinary fees. A reduction in any of these losses means increased profits to dairymen.

Disease can be controlled by two general methods. Treatment is necessary after a disease has become active. It may speed recovery, alleviate loss of some essential function, or even prevent death. Disease almost always results in some financial loss. Such losses would be very much greater, however, if it were not for the services of the veterinary profession.

The other method of controlling disease is to prevent it. This method is by far the most economical. The same applies to accidental injuries. No attempt will be made in this chapter to indicate how various diseases should be treated. This is the responsibility of the veterinary profession. Discussion, however, will deal with methods of preventing disease, an approach that falls within the responsibility of every person concerned with dairy cattle management.

Causes of Disease. Disease is defined as any departure from health which presents marked symptoms, malady, illness, disorder. Actually, the symptoms may vary from those which can be determined only by laboratory tests to abnormalities which can be observed by even the layman. In order to prevent disease one must understand the causes. For practical purposes the causes may be divided into

infectious agents, parasites, foreign bodies, nutritional deficiencies or excesses, physiological imbalances, poisons, and allergies. The effects of each of these causes may be divided into specific diseases.

INFECTIOUS AGENTS. Infectious agents may be divided into bacteria, protozoa, viruses, and fungi. Bacteria are single-celled plants of microscopic size which are found almost everywhere. Protozoa are single-celled microscopic animal organisms found throughout nature. Viruses are very small organisms which can be seen only with the most powerful microscopes. Fungi are very small multicelled plants which do not contain chlorophyll. They are either parasitic or saprophytic in nature.

PARASITES. Parasites may be divided into internal and external ones. The external ones include lice, fleas, mites, flies, etc. The internal parasites include the various types of worms and coccidia.

FOREIGN BODIES. Foreign bodies are generally those objects which are found in the tissues as a result of accident or in the digestive tract as a result of being consumed. This latter category is very common in cattle because the eating habits of this species permits objects such as nails, staples, bolts, wire, etc., to be consumed very easily. Such objects usually are retained in the reticulum, sometimes in relatively large quantities. In some cases, sharp objects will penetrate the wall of the reticulum, the diaphragm, and even the heart. Although veterinarians can operate to remove foreign bodies, such damage frequently results in death. It is now common practice to place a small permanent magnet in the rumen to collect pieces of metal so that they will not result in injury to the animal. "Hardware disease," as it is frequently called, is prevented easiest by the use of good management practices around the farm and barn.

NUTRITIONAL DEFICIENCIES AND EXCESSES. Improper nutrition sometimes has just as serious consequences as infectious diseases. The most widespread nutritional disease frequently is said to be "hollow belly" or not enough to eat. The effect of vitamin and mineral deficiencies are now well known. As yet, however, many people do not realize that excesses of certain nutrients may be just as harmful as deficiencies. This is particularly true with respect to certain vitamins and minerals. Too many people feed livestock on the basis that if a little of something is good, a lot more is better. The science of nutrition is just beginning to indicate the importance of balance in the ration.

PHYSIOLOGICAL IMBALANCE. This disorder has to do with factors such as the various hormones. Normal body activity depends on the various hormones, enzymes, and various life processes being in

balance. When such balances are disturbed through the influence of environment, nutrition, management, or breeding, drastic consequences may result. Such imbalances may affect growth, milk secretion, reproduction, etc.

POISONS. Poisons include materials which have a deleterious effect when they come in contact with the skin or lining of the digestive tract and those which destroy tissue of certain organs or affect their functioning. Extreme care should be taken to prevent animals from eating poisonous weeds or materials such as paint, fertilizer, or industrial wastes. Considerable sleuthing is sometimes required to identify the cause of this type of problem.

ALLERGIES. Allergies are now being recognized in veterinary medicine as in human medicine. Certain drugs, antibiotics, and other materials have been incriminated in this regard.

Diseases Affecting Dairy Cattle. Most of the more common diseases, parasites, nutritional deficiencies, physiological imbalances, and poisons which affect dairy cattle, along with their causes, symptoms, and methods of prevention are listed in Table 27. This table should provide much of the essential knowledge which is needed in understanding the various health problems of dairy cattle and the prevention of these problems. It should be studied at some length.

REPRODUCTIVE TROUBLES. Reproductive troubles are one of the most serious problems faced by dairymen. In general, cows either fail to conceive, or they conceive but fail to carry the fetus full term and an abortion results. Although infection is responsible for many breeding problems, poor management also is a very important factor.

One of the most important management problems is detecting heat periods. Heifers start to come into heat or estrus at puberty. Cows usually start the estrus cycle any time between 3 and 6 weeks after parturition. The time between heat periods usually is 18 to 21 days. A cow may stay in heat 8 to 30 hours with an average of 16 hours. Ovulation occurs about 10 hours after the end of estrus. Estrus is characterized by restlessness, a tendency to mount and to be mounted by other cows, and a slight swelling of the vulva with a flow of mucus. If an animal conceives, further heat periods usually do not occur until after the termination of pregnancy.

Management suggestions which will tend to improve breeding efficiency are listed.

1. Do not breed cows following parturition until all vaginal discharge has ended and at least 60 days have elapsed.

TABLE 27. DISEASES AFFECTING DAIRY CATTLE

Disease	Cause	Symptoms	Control
		Bacteria-Caused Diseases	
Actinobacillosis	*Actinobacillus lignieresi*	Movable swellings under skin, enlarged lymph nodes, and abscesses	Unknown
Anthrax	*Bacillus anthracis*	Sudden staggering, collapse, and death	Strict quarantine of infected premises, cremation of dead animals, destruction of manure and bedding, sanitation, and vaccination
Blackleg	*Clostridium chauvoei*	High fever, gaseous swelling under skin, and usually death	Isolation, sanitation, and vaccination
Brucellosis	*Brucella abortus* (*Br. suis* and *Br. melitensis* occasionally)	Possible abortion, and retained placenta	Testing, slaughter of infected animals, good management, sanitation, and calfhood vaccination
Leptospirosis	*Leptospira pomona*	Abortion, fever, loss of appetite, discolored urine, anemia, and drop or cessation in milk flow	Testing, isolation, sanitation, and good management
Listeriosis	*Listeria monocytogenes*	Walking in circles, loss of appetite, complete paralysis, and death	Sanitation and good management
Mastitis	*Streptococcus agalactiae* plus other species of streptococci, staphylococci, coliform organisms, etc.	Flaky milk, swollen udder, and drop in production	Sanitation and good management, particularly in milking procedures
Paratuberculosis (Johne's disease)	*Mycobacterium paratuberculosis*	Persistent diarrhea, rapid loss of flesh, milk flow drops or stops entirely, and death	Testing infected herds, removal of infected animals, strict sanitation and good management
Pinkeye	*Hemophilus bovis* *Moraxella bovis*	Pink or red around white part of eyeball, temporary blindness, and possible ulcers on eyeballs	Good herd management and treatment

Tetanus	*Clostridium tetani*	Difficulty in chewing and swallowing, jaws become locked, and death	Use of immunizing agents and prompt treatment of injuries
Tuberculosis	*Mycobacterium tuberculosis*	Possible cough, and gradual loss of weight and condition	Testing, slaughter of infected animals, strict sanitation, and good management
Vibriosis	*Vibrio fetus*	Impaired breeding efficiency, and possible abortion	Testing, good management, and artificial insemination with treated semen
	Virus-Caused Diseases		
Foot-and-mouth disease	Foot-and-mouth disease virus	Blisters on mucous membranes of mouth and tongue and between and above claws of feet	Strict quarantine, destruction of infected animals, very strict sanitation, and prevention of importation of animals from countries where infection is present
Rabies	Rabies virus	Anxiety, followed by fear, then violence, paralysis, and death	Control of stray dogs and wild animals in infected areas, quarantine, and vaccination of all dogs
Shipping fever	No general agreement	Chilling, cough, depression, gauntness, and nasal discharge	Prevent exposure to disease, prevent crowding and fatigue, and vaccination
Vesicular stomatitis	Vesicular stomatitis viruses (Indiana and New Jersey types)	Salivation and tearing off of mucous membranes of tongue, lips, hard palate, and gums	Laboratory identification, quarantine, and strict sanitation
Warts	Wart virus	Warts on various parts of body	Good management and vaccination
	Protozoa-Caused Diseases		
Anaplasmosis	*Anaplasma marginale*	Anemia and fever	Sanitation, testing and spraying for insects

TABLE 27 (*Continued*)

Disease	Cause	Symptoms	Control
Bovine coccidiosis	Eimeria (ten to twelve species)	Rough coat, poor appetite, loss of weight, straining when defecating, and diarrhea, often blood tinged	Sanitation and good management
Tick fever (piroplasmosis)	*Babesia bigemina* (a protozoa transmitted by cattle fever tick)	Anemia, bloody urine, emaciation, and low milk production	Eradication of ticks
Trichomoniasis	*Trichomonas fetus*	Reduced milk production, low conception rate, and abortion	Sanitation, rest periods for females, and elimination of infected bulls
		Fungus-Caused Diseases	
Actinomycosis	*Actinomyces bovis*	Immobile enlargement on bone, usually of jaw	Unknown
Ringworm	*Trichophyton album*	Raised circular areas of grayish color on skin	Isolation and treatment
		Parasite-Caused Diseases	
Biting gnats	Black flies or buffalo gnats—genus *Simulium* (at least 80 species) Punkies or sandflies—genus *Culicoides* (about 60 species)	Annoyance of animals and reduced growth and milk production	Eliminate breeding places, use of insecticides
Bladderworms	Gid bladderworm—*Coenurus cerebralis* Thin necked bladderworm—*Cysticercus tenuicollis* *Cysticercus bovis* *Echinococcus granulosus*	None	Sanitation and good management

Cattle grubs	Common heelfly–*Hypoderma lineatum* Northern heelfly–*Hypoderma bovis*	Grub containing swellings on back	Treatment with chemicals
Cattle lice	Biting louse–*Bovicola bovis* Sucking lice– Big long-nosed louse–*Linognathus vituli* Hairy cattle louse–*Solenopotes capillatus* Short-nosed louse–*Haematopinus eurysternus* Tail louse–*Haematopinus quadripertusus*	Poor physical condition, lowered milk production, and lice are visible	Chemical treatment with powders, dip, spray, etc.
Flies	Hornfly–*Haematobia irritans* Stablefly–*Stomoxys calcitrans* Housefly–*Musca domestica* Horsefly–many species of genus *Tabanus* Deerfly–many species of genus *Chrysops*	Lowered milk production, poor growth, and other diseases carried by flies	Sanitary premises, and control of flies by spraying
Liver flukes	Common liver fluke *Fasciola hepatica* Giant liver fluke–*Fasciola gigantica* Large American fluke–*Fascioloides magna* Lancet fluke–*Dicrocoelium dendriticum*	Unthriftiness, lack of condition, and condemnation of livers at slaughter	Elimination of snails, treatment, and good management
Mange	Mites–*Sarcoptes scabiei var. bovis* *Demodex folliculorum bovis*	Skin lesions, itching, loss of condition, and poor growth	Dipping and good management

TABLE 27 (*Continued*)

Disease	Cause	Symptoms	Control
Mosquitoes	About 145 species of genera–*Aedes, Culex, Anopheles, Culiseta, Psorophora,* and *Mansonia*	Annoyance of animals and reduced growth and milk production	Eliminate breeding places, and use of insecticides
Roundworms of digestive tract	Stomach– Large stomach worm–*Haemonchus placei* Medium stomach worm–*Ostertagia ostertagi* Small stomach worm–*Trichostrongylus axei* Small intestine– Cattle hookworm–*Bunostomum phlebotomum* Cooper's worm–*Cooperia species* Small hair worm–*Trichostronglyus colubriformis* Intestinal thread worm–*Strongyloides papillosus* Thread-necked *strongyle*–*Nematodirus* species Cattle ascarid–*Neoascaris vitulorum* Large intestine– Whipworm–*Trichuris* species	Anemia, stunting, and unthriftiness	Sanitation, good management, and treatment

	Nodular worm—*Oesophagostomum radiatum*		
	Large-mouthed bowel worm—*Chabertia ovina*		
Scabies	Mites—*Psoroptes equi var. bovis* *Chorioptes bovis*	Skin lesions, itching, loss of condition and poor growth	Dipping and good management
Screwworm	Screwworm fly—*Callitroga hominivorax*	Infested wounds	Good management, prompt treatment wtih insecticides, and release of sterile male flies
Tapeworms	*Moniezia expansa* *Moniezia benedeni* *Thysanosoma actinioides*	Unthriftiness	Sanitation and good management
Tick fever (piroplasmosis)	*Babesia bigemina* (a protozoa transmitted by cattle fever tick)	Anemia, bloody urine, emaciation, and low milk production	Eradication of ticks
Ticks	Various organisms carried by ticks or annoyance by ticks themselves	Vary with the disease carried, irritation of skin, and possible anemia	Treatment of habitants of ticks and treatment of animals
Verminous dermatitis	Filarial roundworm—*Stephanofilaria stilesi*	Skin lesions	Sanitation and good management
Verminous pneumonia	*Dictyocaulus viviparus* (lung worms)	Cough, panting, and frequent death	Sanitation and good management
		Physiological Imbalances	
Grass tetany and wheat-pasture poisoning	No general agreement	Tetany in animals on early, lush pasture, and frequent death	Feeding hay to animals on pasture
Ketosis	Improper functioning of endocrine system	Low milk production, poor appetite, low blood glucose, and high blood ketones	Liberal feeding after parturition, feeding propionates and lactates, etc.
Milk fever	Inactive parathyroid glands	Low blood calcium and tetany soon after parturition	Feed 20,000,000 I.U. vitamin D daily for 5 to 7 days prepartum

TABLE 27 (*Continued*)

Disease	Cause	Symptoms	Control
	Common Nutritional Deficiencies		
B complex vitamins	Inadequate ration of young calves or abnormal rumen activity in older cattle	Vary with deficiency, produced only experimentally	Feed normal diets
Bloat	Composition and physical nature of feed, and makeup of animal	Distention of rumen by retained gasses	Proper management and feeding
Calcium deficiency	Inadequate calcium intake	Fragile bones and reduced milk yield	Feed calcium supplement
Cobalt deficiency	Inadequate cobalt intake	Poor appetite, emaciation, and poor growth and milk production	Feed a cobalt supplement
Common salt deficiency	Inadequate salt intake	Intense craving for salt, lack of appetite, and rough hair coat	Feed salt supplement
Copper deficiency	Inadequate copper intake or excess molybdenum consumption	Scouring, fading of hair coat, and anemia	Feed copper supplement
Goiter	Inadequate iodine intake	Goiter or big-neck in calves at birth	Feed iodized salt or other iodine supplement
Iron deficiency	Inadequate iron intake	Anemia (rare except in young calves)	Feed iron supplement
Magnesium deficiency	Inadequate magnesium intake	Irritability, loss of appetite, and convulsions in calves only	Feed concentrates, hay or magnesium supplement
Phosphorus deficiency	Inadequate phosphorous intake or excessive calcium consumption	Depraved appetite, stiffness of joints, low inorganic blood phosphorous and broken bones	Feed a phosphorous supplement
Rickets	Inadequate intake of vitamin D	Roached back and stiff joints especially in calves	Exposure to sunlight, feeding of sun-cured hay or vitamin D supplement

Vitamin A deficiency	Inadequate intake of vitamin A or carotene	Night blindness, scouring, and unthriftiness	Feed pasture, green leafy hay, hay-crop silage or carotene or vitamin A supplements
		Poisons	
Arsenic poisoning	Consumption of arsenic	Intense abdominal pain, convulsions, and death	Prevent intake of arsenic
Fluorine poisoning	Consumption of excessive fluorine	Mottling of teeth, enlarged joints, and lameness	Prevent excessive fluorine intake
Hyperkeratosis	Highly chlorinated naphthalene	Listlessness, drooling, emaciation, and dry, scurfy skin	Keep oils and greases containing causative agent away from cattle
Lead poisoning	Consumption of excessive materials containing lead	Inflammation of lining of stomach and intestines, diarrhea, animals walk in circles, and blindness	Prevent consumption of paint, battery plates, and lead sprays
Molybdenum poisoning	Consumption of excessive molybdenum	Diarrhea, anemia, and fading of hair coat	Reduce molybdenum intake or increase copper intake
Nitrate poisoning	Consumption of plants, water, or chemicals high in nitrate	Staggering gait, blue coloration of mucous membranes, and death	Good management and treatment
Salt poisoning	Excess consumption of common salt	Hypersensitivity to touch, loss of appetite, and loss of coordination	Allow free access to common salt at all times
Selenium poisoning	Consumption of plants high in selenium	Animals sterile or slow breeders, rough horns, and long and deformed hoofs	Avoid feeds high in selenium

2. Keep an accurate record of dates of parturition, heat periods, services, etc.

3. Breed cows near the end of the heat period.

4. Have a competent veterinarian make an examination in cases of failure to come into heat, irregular heat periods, abortions, and retained placentae, and follow his recommendations as to correction of the problem.

5. Use proper sanitation, isolation, and care when disease is found in the herd.

6. Have regular pregnancy examinations by a competent veterinarian.

In some cases the physiological make-up of the animal is such that normal results are not obtained. The veterinarian can correct such conditions in some cases.

Infection is the most dreaded cause of reproductive trouble. It may result in early embryonic mortality during the first few weeks of pregnancy or the more common form of abortion after a few to several months. The early embryonic mortality usually is thought to be a failure to conceive. It probably is much more common than generally thought.

The infectious diseases which frequently cause reproductive problems are Brucellosis, vibriosis, trichomoniasis, and leptospirosis. Brucellosis is the most common of these diseases, and its eradication and control are being carried out by joint state-federal programs in the various states. This disease has particularly important human health aspects. It can be controlled rather effectively in cattle by the vaccination of calves between the ages of 6 and 8 months with Strain 19 vaccine. This vaccine does not give complete immunity to the disease but does result in considerable resistance to it. In most states there is no well-organized testing program for the other diseases. They generally are tested for when a problem herd is found to be negative for Brucellosis. One cannot cure Brucellosis by treatment. The other diseases generally are cured by giving cows a sexual rest, but treatment may hasten the recovery period. Leptospirosis outbreaks may be controlled by vaccination.

MASTITIS. Mastitis probably produces a greater loss to the dairy industry than any other infectious disease. It is an inflammation of the mammary gland and generally is caused by one of several different organisms. It may cause milk to be unsaleable or result in the temporary or permanent loss of one or more quarters of an udder. *Acute mastitis* is the type which results in a sudden inflammatory

swelling of the udder and the cow's going off feed. Veterinary treatment and very frequent milking usually are necessary. *Chronic mastitis*, which affects an udder over a period of time, does not result in the previously mentioned symptoms but is characterized by the production of flaky milk, a decrease in production, and the development of lumps in the secretory tissue. In general, mastitis is caused by streptococci and staphylococci. Mastitis caused by *Streptococcus agalactiae* is vulnerable to many antibiotics and can in most cases be cured. Other streptococcus species, staphylococci, and other infections usually are not eliminated by treatment. A bacterin-toxoid used experimentally has produced some resistance to staphylococcus forms of mastitis.

The only really satisfactory way to control mastitis is to prevent it by means of good management. Some of the most important management factors are listed.

1. Follow good milking procedures.
2. Use a strip cup at every milking.
3. Prevent udder injuries.
4. Provide adequate bedding.
5. Prevent exposure of cows to drafts and damp beds.
6. Breed and select for desirable shaped udders.
7. Follow a routine testing program under the supervision of a veterinarian.
8. Treat in early stages of infection.
9. Isolate or eliminate potential spreaders as quickly as possible.

Many dairymen have almost eliminated mastitis as a disease problem by testing, treatment, and good management.

KETOSIS. Ketosis is a physiological disturbance which may affect cows anytime between a few days and several weeks after parturition. It is characterized by a drop in production, a lack of appetite, a sweetish odor on the breath, high ketone body and low sugar levels in the blood, and the excretion of ketone bodies in the urine. It apparently is caused by improper functioning of the adrenal glands, plus a lack of carbohydrates.

The objective in treating affected animals is to raise the blood sugar level to normal by injecting glucose or certain hormones into the blood stream and by feeding sodium propionate or a mixture of sodium and calcium lactates. The feeding of molasses is not a good means of increasing blood sugar because its sugar is fermented into volatile fatty acids in the rumen and not absorbed as glucose. It may help, however, by stimulating feed consumption. This disease usually

affects high producing cows and may be very troublesome in a particular herd one year and not another. It may affect cows in certain herds in a community but not others. The reason for this situation is not known.

MILK FEVER OR PARTURIENT PARESIS. This disease frequently is confused with ketosis, but the conditions are entirely different. Milk fever usually occurs within the first three days after parturition and is characterized by inability to rise, paralysis, partial or total loss of consciousness, and a low blood calcium. The symptoms are due to the low blood calcium and the disease is treated by injecting a calcium solution into the blood stream. Low blood calcium apparently results from the inability of the parathyroid glands to mobilize calcium quickly enough to replace that removed in the secretion of milk following parturition. The feeding of 20,000,000 International Units of vitamin D per day for 5 to 7 days previous to parturition is rather effective in preventing the condition. This preventive treatment, however, should not be continued beyond 7 days.

BLOAT. Bloat is a condition of ruminants in which the rumen and the reticulum are distended with gas. The condition may vary from mild to very severe. It may vary from very frothy to no froth at all. The condition usually is associated with the consumption of young legume pasture, but such pasture frequently produces no bloat at all. There are numerous theories on the cause of bloat, but it is still not entirely understood. It appears that bloat is not due to the production of abnormal amounts of gas in the rumen but to the abnormal retention of the gas. It is not clear whether bloat is caused by the presence of some substance in the forage, to the production of some factor in the fermentation process, or to the physical condition of the feed.

In any case, the problem is to prevent bloat or to relieve the condition before it has harmful or fatal results. Prevention can usually be insured by feeding cattle concentrate before they are turned on pasture and by having hay available free choice. Animals which are turned on legume pasture in a hungry condition are the most susceptible to the condition. The feeding of salt containing penicillin and the feeding of certain detergents also have been used to prevent bloat. In cases of severe bloat, the condition can sometimes be relieved (1) by holding the mouth open by means of a rope or stick and then walking the animal, or (2) by introducing a stomach tube into the rumen. In cases of emergency, the condition can be relieved by puncturing the rumen with a trocar and cannula, or even

a pocket knife, in the triangular space in front of the left hip. Sometimes immediate action is required to prevent death of an animal.

CALF SCOURS OR CALF DIARRHEA. Scours is divided into two general classes. *Digestive scours* is due to the feeding of too much milk or milk replacer, dirty utensils, variable temperatures and amounts of milk, irregular feeding times, etc. It may occur at any time during the milk feeding period. It generally can be corrected by eliminating the cause and cutting the feed in half for two feeds.

Infectious scours generally affects calves at birth or within 6 to 72 hours. The calf may be found in a cold, weak, and dying condition. Eyes become sunken due to dehydration. In other cases calves may scour mildly or severely during the first month of life and then recover with little treatment. In general, however, the calves become unthrifty, pot-bellied, show poor growth, and get pneumonia. Several different organisms including *Escherichia coli* may cause infectious scours. Some have not been identified.

The more severe forms of the disease usually cannot be treated with any degree of success. For a period almost all calves may die, then the condition may gradually disappear and no trouble will be experienced for several years. In such cases, it appears that some resistance may be built up in the herd.

In cases of severe infection, some benefit is obtained by having calves born in a stall which has been cleaned very thoroughly and then isolating each one from other animals in a clean, warm place and feeding from clean utensils. Having calves born in a clean pasture or paddock for a period of several months seems to be helpful in breaking the cycle of the disease.

CALF PNEUMONIA. Pneumonia also is a troublesome disease of dairy calves. Symptoms include dullness, coughing, rapid breathing, a temperature of 103° F to 106° F, and a nasal discharge. The calf loses its appetite and body condition. The hair becomes rough, diarrhea develops, and prostration and death may occur in a few hours or days in acute cases. With prompt treatment and good care, calves may be saved, but lung damage frequently is extensive and may prevent such animals from developing into normal, productive individuals. The only sound approach to the problem of calf pneumonia is to prevent it by good feeding and good management.

For more detailed information on these diseases and those listed in Table 27, it is suggested that the excellent references listed at the end of this chapter be consulted. The services of a qualified veterinarian should be obtained to prescribe treatment.

Disease Prevention. The prevention of disease, poisoning, and accidents depends more on common sense than on any other factor. It depends on doing those things which most dairymen know should be done, but which often are neglected until one finds himself in trouble. The measures required are not difficult or expensive. They do require constant vigilance.

A sound basis for maintaining a healthy herd is provided by the following:

1. Good care of animals.
2. Adequate feed.
3. Adequate shelter.
4. Isolation or elimination of diseased animals.
5. Purchase of only healthy animals.
6. Guarding against disease carriers.
7. Breeding for disease-resistant qualities.
8. An adequate testing program.
9. An adequate vaccination program.
10. Sanitary practices and premises.
11. Proper use of veterinary services.

Good care means gentle care, regular and complete milking, adequate bedding, stalls that are large enough, adequate light and ventilation in the barn, enough exercise, the use of gritty material on the floors to prevent slipping, freedom from drafts, good fences, trimming of feet when needed, and prompt treatment of minor illness and injuries. Although all of these factors are only indirectly related to disease, they are very important in keeping animals healthy. Many of these factors are related to injury, but injury frequently leads to infection. This is particularly true as far as the udder is concerned.

Adequate feed refers to the proper amounts of protein, energy, vitamins, minerals, and water. Though improper nutrition probably has little relationship to the incidence of infectious diseases, many of the nutritional diseases are nearly as detrimental as many of the infectious ones. This statement is particularly true of such problems as cobalt deficiency, goiter, vitamin A deficiency, and rickets. Adequate feed is essential for good health.

Adequate shelter for dairy cattle calls for a dry place which is free from drafts. Low environmental temperatures are not harmful if animals are used to them. High temperatures have a very marked adverse effect on feed consumption and milk production. A shed open on one side meets the housing needs of dairy cattle of all ages, even in very cold climates, if they are allowed to run loose. Drafts

and dampness reduce resistance and increase the incidence of disease.

Since diseased animals usually are potential spreaders, they should be isolated or eliminated from the herd as quickly as possible. Diseases which can be treated successfully usually are handled by isolation. Diseases which cannot be treated successfully, such as Brucellosis and tuberculosis, require prompt elimination if at all possible. Isolated animals should be handled in such a way as to minimize carrying the infection to other animals. Strict sanitation, including adequate cleaning and disinfection, should be carried out while infected animals are on the farm and after they are cured or eliminated.

Purchased animals must be proven free of infectious disease before they are brought to the home farm. This examination should include testing for Brucellosis, tuberculosis, mastitis, and vibriosis. It is important to know the health status of all animals in the herd from which purchases are made. If other animals are infected, the ones being purchased might be in the incubation stage of infection and thus be potential spreaders. A single infected cow has in many cases been directly responsible for the loss of an outstanding herd of cattle from disease. A dairyman cannot be too careful in buying cattle from other herds.

Disease carriers of other sorts also should be guarded against. Such carriers include rats, stray dogs, other types of farm animals, dealers' trucks, polluted streams, and visitors walking through the feed alleys. Brucellosis has been spread by many of these means. Certain other diseases usually are spread only by contact. One should know what diseases are affecting his neighbors' livestock and take precautions to prevent their spread by any means. In certain cases it may be wise to keep animals from being pastured in a field which adjoins a neighbor's pasture where infected cows are kept. Common sense is a wise guide in this matter.

Although disease as such is not inherited, weaknesses which increase susceptibility are inherited. The outstanding example is the type of udder which is susceptible to mastitis. A pendulous udder may be inherited. Such an udder is more subject to bruising and injury than a well-supported udder. Injuries of the udder and teats predispose to infectious mastitis. One wonders if the success which the plant breeder enjoys in breeding for disease resistance could not be carried over to animal breeding.

An adequate testing program is an essential phase of dairy herd management. In clean herds Brucellosis and tuberculosis tests should be carried out once a year—more often in herds where there is some infection. These testing programs are generally supervised by the

department of agriculture of each state in cooperation with the U.S. Department of Agriculture. Infected animals may be removed from the herd under an indemnity payment plan. The frequency of testing should depend on the extent of the infection. In cases where infectious abortions occur in a Brucellosis-free herd, tests for vibriosis should be carried out routinely if infection is present. Other special tests may be necessary. The main purpose in carrying out a testing program is to detect infected animals before the disease has a chance to spread to other animals. Infected animals must be promptly isolated and treated or eliminated from the herd.

The need for vaccination depends on the presence of certain diseases in the herd or in the community. In an area where there is no blackleg, vaccination against this disease is not necessary. If the disease is found in the area, vaccination may be very desirable. The same principle applies to Brucellosis. Strain 19 vaccine is of much help in preventing and controlling this disease, but many breeders prefer not to use it in a clean herd in a clean area. There is no vaccine available to prevent most diseases.

Good sanitation includes keeping premises clean, the use of clean equipment, prompt removal and proper disposal of afterbirths and mastitic milk, and adequate disinfection of premises and equipment after disease has been found. Sanitary procedures should be based on the prevention of disease and not on the elimination of it after its occurrence.

Every dairyman should have available when needed the services of a competent veterinarian. The veterinarian should have the same role in caring for the dairy herd that the family physician has in looking after the health of the farm family. The veterinarian should know the herd and advise on methods of keeping it healthy. He should be consulted when the first signs of disease appear and recommend methods for its control. He should be treated as a highly trained professional person, whose directions are to be carried out conscientiously and whose fees are to be paid when due. He should not be expected to perform miracles, however, when he is called as a last resort after home remedies have failed.

QUESTIONS

1. Why should disease be controlled? How?
2. What is disease?
3. What types of infectious agents cause disease in dairy cattle?

4. List two diseases which are caused by each.
5 How do you tell when a cow is in heat?
6. Describe the normal estrus cycle.
7. How should mastitis be controlled?
8. Describe methods for controlling bloat.
9. Describe the control of calf scours.
10. What affect has pneumonia on calves?
11. What are the differences between ketosis and milk fever?
12. What general types of parasites affect dairy cattle?
13. Why are foreign bodies particularly troublesome with dairy cattle?
14. List ten rules for maintaining a healthy dairy herd.
15. Explain each item listed in number 14.
16. Explain the proper role of the veterinarian in maintaining a healthy herd.
17. What diseases of dairy cattle are particularly troublesome on your home farm and in your community?
18. What measures are being taken to control the diseases mentioned in number 17?
19. Find out what training the typical veterinarian in your community has.
20. How should a dairyman use the services of his veterinarian?

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CHAPTER **12**

The Babcock Test for Milk and Milk Products— Application of the Test

History and Uses. As shown in Chapter 3, milk and cream vary greatly in composition, notably in butterfat content. Prior to 1890, milk and cream were sold by volume, regardless of composition. It was long recognized that there was a dire need for a more equitable basis of payment. Finally in 1890, Dr. S. M. Babcock of the University of Wisconsin developed the butterfat test that bears his name. After all these years, the test is still in use, and although there have been some equipment refinements, the basic principles of the test remain the same. Before describing the test, its uses will be explained so that its importance will be fully understood.

AS A BASIS OF PAYMENT FOR MILK OR CREAM. In buying milk for bottling purposes, the common practice is to pay x dollars per cwt for milk with some basic butterfat content, such as 3.5 per cent plus or minus a factor of 4 cents to 6 cents per 0.1 per cent butterfat above or below the base of 3.5 per cent. The butterfat premium depends on the market price of butter. Thus the price might be $5.00 per cwt for 3.5 per cent milk plus or minus 6 cents for each 0.1 per cent over or under 3.5 per cent. If the milk tested 3.9 per cent butterfat, the final price would be $3.9 - 3.5 = 0.4 \times 6$ cents $= 24$ cents + $5.00 = $5.24 per cwt.

In handling cream for purposes other than buttermaking, it is commonly bought and sold on the basis of a 40-qt can of 40 per cent butterfat product. The price is determined by the supply and demand and the market price of milk and butter. The per can price is figured from the butterfat contained in the cream. The weight of a 40-qt can of 40 per cent butterfat cream is 82.5 lb, which means a can of this cream contains $82.5 \times 0.40 = 33$ lb of butterfat. If the price of butterfat is \$.90 per lb, a can of cream would sell for $33 \times \$.90 = \$29.70$ per can. Conversely, if one paid \$27 per can for 40 per cent cream, butterfat would be costing him $\$27.00 \div 33 = \$.818$ per lb.

When the producer sells milk or cream to a creamery for buttermaking purposes, it is sold on what is called straight butterfat basis. This is because butter contains about 82 per cent butterfat. Milk or cream is weighed and then tested by the Babcock test at the creamery. If, for example, a producer delivers 500 lb of 4 per cent milk, he would be paid for $500 \times 0.04 = 20$ lb butterfat at a price determined by the market price of butter. Similarly, 100 lb of 35 per cent cream would equal $100 \times 0.35 = 35$ lb of butterfat to be paid for.

IN DETERMINING THE ANNUAL BUTTERFAT PRODUCTION PER COW. Since butterfat is important when milk is sold on the basis of weight and test and all-important when milk and cream are sold on a straight butterfat basis, it becomes essential for the producer to know both the weight of milk and the weight of butterfat produced by each cow in his herd. Only by knowing this can he improve his herd by selecting the best producing cows and bulls from the best producing cows for breeding purposes.

The application of the Babcock test and the scales to this work are discussed in another chapter. The ideal is to have a herd of heavy milk producers, whose milk also tests reasonably high in butterfat. Because the breeds of cows giving the largest quantity of milk give milk of the lowest per cent of butterfat and since some strains of cows in each breed give higher butterfat testing milk than others, it becomes evident that the Babcock test is a great help to the dairyman in producing milk at a profit.

Thus, if one were selling milk on any basis, a cow giving 5,000 lb of 4 per cent or 200 lb of butterfat in a year would obviously be considered a boarder as compared to one producing 10,000 lb of 3.5 per cent milk or 350 lb of butterfat in a year. The money derived from the extra milk and butterfat would not be clear profit, because it would undoubtedly cost more to feed the second cow and handle her milk. This example shows that real business principles must be used

in producing milk at a profit, in that costs as well as returns must be known.

IN CHECKING MILK FOR ADDED WATER AND IN DETERMINING THE SOLIDS-NOT-FAT CONTENT IN MILK. Prior to the time of the Babcock test, many an unscrupulous farmer would add some water to milk and hence get paid for a larger volume. Occasionally one may try to get away with this practice today, but periodic checking by the milk company is almost sure to detect the practice. Dilution can be detected by testing the milk for butterfat and specific gravity and applying a formula to determine the solids-not-fat or total solids. This test, which will be described in Chapter 13, is applicable in the evaporated milk industry, where the finished product must comply with both butterfat and total solids standards.

Because of the fact that margarine has replaced about one-half of the former butter sales and because the public is becoming more and more diet conscious, the solids-not-fat content is assuming more and more importance and may in time be a factor in the buying of milk.

STANDARDIZING MILK OR CREAM. Altering the normal butterfat content of milk or cream by the addition of cream or skim milk is known as standardization. In some states the standardization of milk for sale as such is forbidden by law, but some standardization occurs naturally when the milk from a number of producers is run into a large storage tank in a plant. Accurate standardization is accomplished by testing the products to be standardized for butterfat, knowing the weight of the standardized product desired, and then applying the Pearson square formula.

For example, suppose one wishes to standardize 1,000 lb of 5 per cent butterfat milk to 3.7 per cent butterfat by using skim milk.

5 — 3.7 parts of 5 per cent milk

3.7

0 — 1.3 parts of skim milk

$1{,}000 \div 3.7 = 270.2$ lots of 3.7 lb each of 5 per cent milk

$270.2 \times 1.3 = 351.3$ lb of skim milk required making a total of $1{,}000 + 351.3 = 1{,}351.3$ lb

Proof: $1{,}351.3 \times 0.037 = 49.99$ or 50 lb of butterfat

1,000 lb of 5 per cent milk contains 50 lb of butterfat

Butterfat in skim milk 0

Suppose one wishes to prepare 1,000 lb of 30 per cent cream from 40 per cent cream and 3.5 per cent milk:

40 26.5 parts of 40 per cent cream

30

3.5 10 parts of 3.5 per cent milk

36.5 parts of 30 per cent cream

1,000 ÷ 36.5 = 27.39 times 26.5 lb of cream and 10 lb of 3.5 per cent milk must be used.

27.39 × 26.5 = 725.8 lb of 40 per cent cream

27.39 × 10 = 273.9 lb of 3.5 per cent milk

999.7 or 1,000 lb of 30 per cent cream

Proof: 1,000 lb of 30 per cent cream	= 300	lb butterfat
725.8 × 0.40 " " "	= 290.32	lb butterfat
273.9 × 0.035 " " milk	= 9.58	lb butterfat
	= 299.90	or 300 lb butterfat

Standardization probably requires the most common mathematical calculation in the processing operation. It must be done in connection with the manufacture of most dairy products, such as the manufacture of cheese, condensed or evaporated milk, ice cream, and whole milk powder where a certain butterfat content in the finished product is desired to satisfy legal or company standards.

DETERMINING THE BUTTERFAT CONTENT OF PRODUCTS SOLD. All dairy products are prepared for sale with a specified butterfat content and all must comply with state and federal laws with respect to percentage of butterfat. A substandard product can get a company into trouble with the law and an overstandard product can cost the company a lot of money. Thus a company selling 50,000 qt or 107,500 lb of milk a day that is supposed to test 3.7 per cent butterfat would lose $107.50 per day if the milk tested 3.8 per cent butterfat if butterfat was valued at $1.00 per lb.

107,500 × 0.001 = 107.5 lb butterfat @ $1.00 per lb = $107.50

If a plant makes 10,000 gal or 47,500 lb of ice cream a day, and it is supposed to test 12 per cent butterfat but actually tests 12.3 per cent, the plant would lose

47,500 × 0.003 = 142.50 lb butterfat @ $1.00 per lb = $142.50

These examples are sufficient to indicate the great importance of the Babcock butterfat test in this particular application.

BUTTERFAT ACCOUNTING. A plant receives and pays for a certain amount of butterfat in a given time. The milk or cream containing this butterfat that is used for various purposes must be accounted for. The Babcock test and scales enable the plant to account for

BUTTERFAT LOSS ANALYSIS REPORT
(Milk Plant)

	Pounds of B.F.	Per Cent to Total
1. Opening Inventory		
Receipts		
2. Producers		
3. Country stations		
4. Outside purchases		
5. Chocolate fat used		
6. Total fat received		
7. Total fat paid for		
8. Receiving (gain or loss)		
9. Total fat to be accounted for		
10. Butterfat loss analysis (gain or loss)		
11. Production		
12. Separating		
13. Standardizing		
14. Butter operation		
15. Creamed cottage cheese		
16. Ice cream mix		
17. Unaccounted (includes bottling, can filling)		
18. Milk		
19. Cream		
20. Other		
21. Total production		
22. Sales		
23. Employees		
24. Breakage in coolers		
25. Route shortage (samples and breakage)		
26. Losses due to returns		
27. Loss in Dumping		
28. Discard (chocolate, buttermilk, and cheese)		
29. Difference between sales cooler returns and amount received by production		
30. Unaccounted (inv. losses)		
31. Bottle coolers		
32. Bulk coolers		
33. Total sales		
34. Unaccounted		
35. Total production and sales		
36. Less: employees' usage		
37. Total Per Cent Butterfat Lost		

Fig. 51. Butterfat loss analysis report.

the butterfat in various products; the sum of these lots can be compared with the quantity purchased. The difference is known as butterfat loss. It is the job of the production manager, working with the accounting department, to keep this loss to a minimum. A butterfat loss analysis form, Fig. 51, is used for recording results. It will be seen that without the Babcock test this could not be done. It also will be noted that some butterfat losses occur in skim milk when separating cream from milk, in buttermilk in the process of churning, and in whey in cheesemaking. Modifications of the Babcock test which permit its use on these products enable the operator to trace these losses.

THE SAMPLING OF MILK AND CREAM

Importance of Obtaining a Correct Sample. In making the Babcock test on a quantity of milk or cream, it must be borne in mind that the percentage of butterfat is the unknown that is to be determined. Therefore the sample to be tested must accurately represent the lot of milk or cream from which it is taken. The main reason why the sampling of milk is difficult and requires the exercise of great care, is that the butterfat is the lightest part of milk, and thus does not remain evenly distributed throughout the tank, can, or bottle of milk. If the constituents of milk, including the butterfat, all had the same specific gravity, it would be easy to sample. Since this is not the case, the heavier constituents, by the law of gravity, settle to the bottom in the form of skim milk, and the butterfat rises to the top in the form of cream. It is obviously essential that the cream and skim milk be thoroughly mixed before sampling.

Conditions Met in Sampling Milk and Cream. FRESHLY DRAWN MILK. This is the most common condition encountered on the farm. If one wants to test the milk of his cows occasionally, or to have it tested by a dairy herd improvement association, the one doing the work is confronted with the problem of sampling warm milk, fresh from the cow. An accurate sample can be dipped directly from the pail as soon as the milk is drawn. The speed of the milker and the amount of milk that a cow gives enter into the problem, however, and it is recommended, in sampling freshly drawn milk, that it be poured once into an empty pail before dipping out the sample.

COLD CANNED MILK. Suppose an inspector wishes to get a sample out of a can of cold milk at a railroad station platform, or from a

truck, milk car, or milk plant. How should he go about it? The cream has risen to the top, with the result that there are possibly 6 to 8 in. of cream at the top of the can. This cream is cold and is sticking around the neck and under the shoulder of the can. Although there is no way to warm the milk, the cold cream must be thoroughly mixed with the skim milk beneath. There are two possible methods: the milk may be poured back and forth several times into an empty can until no streaks of cream appear, or a can-stirrer may be used for mixing the milk in the original can. The pouring is much to be preferred. The can-stirrer works well when the can is not full of milk, so that the milk can splash around when it is stirred. But when the can is full, the stirrer is likely to leave some cream sticking up under the shoulder of the can about the neck, unless it is very carefully used.

The same statement applies to the sampling of cream. When a can of cold cream has stood for some time, the richest cream is at the top, with thinner cream underneath.

In obtaining a sample of bottled milk from a delivery truck, one full bottle is usually taken. This sample is sent to the laboratory, where it can be warmed and properly mixed before testing. If it is necessary to send only a small sample to the laboratory, the bottle of cold milk must be poured into an empty bottle and then poured back and forth several times.

What has been said applies to sampling milk for chemical analysis. When milk is sampled for bacterial analysis, all receptacles, stirrers, and samplers must be sterilized before using, and the samples should be iced and shipped to the laboratory at once.

At the dairy plant the sampling of the incoming cold milk is done as the milk is being dumped and weighed. The milk delivered by each farmer is dumped from the cans into the weigh tank, which is a tank mounted on an automatic scale. Almost immediately after the milk is dumped into the weigh tank, the scale comes to the balance, the weight of the milk is obtained, a sample of the milk is taken by means of a dipper or sampling tube and is transferred to the sample jar, and the milk is then released from the weigh tank to a receiving vat.

It usually is assumed that the violent mixing which occurs when milk is dumped into the weigh tank is sufficient to produce a uniform distribution of the fat through the milk. The usual practice is to take the sample promptly, without any further stirring of the milk. Experiments have shown, however, that samples taken in this way are sometimes inaccurate. Since the cream has risen toward the

top of the can, the last milk to be dumped is lowest in test. If a sample is drawn where the last milk entered the weigh tank, a lower test sometimes results. The type of weigh tank makes a difference—for example, the shape of the tank and whether or not it is equipped with a strainer and baffles. Some weigh cans are equipped with motor-driven agitators. Since there is a difference in weigh tanks, each one should be tested in order to see if the dumping of milk does adequately mix the milk so that accurate samples can be taken in the manner described above.

BULK TANK MILK. The trend is for the producer to give up the use of milk cans and to place the milk directly in a refrigerated tank located in a milk house or room. These tanks are supplied with mechanical agitators so that the driver of the tank truck that picks up the milk for the plant can stir the milk prior to sampling.

PARTLY CHURNED MILK. In warm weather, cans of milk only partly full, with some of the butterfat churned into particles of butter, may arrive at the milk plant. Unless this milk can be homogenized, it is impossible to accurately sample it and obtain a correct butterfat test. An approximation of the butterfat content may be had by warming the milk to about 110° F, to melt the butter, and then agitating thoroughly and drawing the sample.

FROZEN MILK AND CREAM. In winter, milk and cream sometimes arrive at the creamery partly frozen. When a can of milk or cream freezes, the freezing begins at the outside of the can, usually leaving an unfrozen core in the center. The unfrozen part usually contains less butterfat than the frozen part, if the milk or cream is badly frozen. The ice that forms near the edge of the can below the cream line on milk, or below the line of richest cream on a can of cream, is low in butterfat; but most of the cream under the shoulder of the can freezes solid and frequently freezes over the top, so that the small unfrozen portion in the center tests less than the whole. At any rate, frozen milk and cream test differently, and the can of milk or cream must be slowly warmed in a tank of hot water before mixing and sampling. Heating should be done slowly, in water not much hotter than 130° F. If the can is heated quickly in boiling water, some of the butterfat in the cream will melt, which gives rise to the oily condition existing in partly churned milk that has been heated. In the milk plant, the procedure described above must be followed before the milk can be emptied into the weigh can to be weighed and sampled.

SOUR MILK OR CREAM. A can or small sample of milk that is extremely sour or old, with the curd quite firm, cannot be practically

tested with any degree of accuracy. Cream seldom thickens in this way, because of the excess of butterfat and low casein content. Therefore, sour cream can be sampled like sweet cream.

A can of sour milk that is just thickening can be sampled best by pouring from one can to another several times, through a wire sieve of fairly fine mesh. This straining breaks up the soft curd and gives a more uniform mixture. The sample is then taken out.

Unless absolutely necessary, churned, frozen, or sour milk should not be sampled and tested. Milk in any of these forms cannot usually be tested accurately. If a normal sample of the same milk cannot be obtained, however, and sampling of the churned, frozen, or sour milk is necessary, this fact should be kept in mind when appraising the results of the test.

The Composite Sample. What has been said thus far applies to the taking of a single sample from a given lot of milk or cream. A composite sample is a mixture of single samples taken from different lots of milk or cream, the amount taken each time being in the same proportion to the amount of the milk or cream sampled. In other words, a composite sample is a proportionate mixture of two or more lots of milk. For example, a cow gives 20 lb of 3.5 per cent milk in the morning and 15 lb of 4 per cent milk at night. If 1 ml of milk were taken for each pound in the 20-lb lot and mixed with 1 ml for each pound in the 15-lb lot, the result would be 20 ml plus 15 ml, or 35 ml. This mixture would be a true composite sample and should test the same as if the two lots of milk had been sampled separately and the average test calculated as follows:

$$\begin{array}{ll} 20 \times 0.035 & = 0.70 \text{ lb butterfat} \\ 15 \times 0.04 & = 0.60 \text{ lb butterfat} \\ \overline{35} \text{ lb milk} & \quad \overline{1.30} \text{ lb butterfat} \end{array}$$

$$1.30 \div 35 \times 100 = 3.71 \text{ per cent, average test of milk}$$

On the other hand, if equal amounts of milk, say 25 ml, had been taken from the morning's and night's milk and mixed together, the mixture would not be a composite sample, as it would not be in proportion to what the cow actually gave. This method would place in the sample as much of the 4 per cent milk as of the 3.5 per cent milk. The test would then be too high, for

$$3.5 + 4 = 7.5 \text{ per cent}$$

$$7.5 \div 2 = 3.75 \text{ per cent}$$

whereas,

3.71 per cent is correct

The composite sample is very commonly used in creameries and milk plants and in record keeping on the farm to save time and labor.

As an illustration of its use on the farm, we may assume that it is desired to find out the number of pounds of butterfat produced by a cow in a week. If each milking were weighed and tested separately, there would be required fourteen distinct tests, the multiplying of each test by the number of pounds of milk sampled in each case, and the adding of results to obtain the number of pounds of butterfat. Now, if each milking is weighed and a weekly composite sample made up, only one test is required; and this test, multiplied by the number of pounds of milk for the entire week, would represent the pounds of butterfat for the week.

By way of illustrating the use of the composite sample in a milk plant, let us suppose that the plant has 300 patrons. Single sampling would mean 300 tests a day, an impracticable undertaking. A composite sample of each patron's milk, made up and carried for 2 weeks as is a common custom, would mean only 300 tests twice a month, an obvious and large saving of time and labor.

Method of Taking Composite Samples. There are four general methods of taking composite samples: they may be taken by means of the graduated pipette, the sampling tube, the half-ounce dipper, or the automatic sampler.

The graduated pipette is adapted to the taking of composite samples in the case of some types of farm-record keeping and in experimental work in which extreme accuracy is required. The one in common use is graduated in tenths up to 25 ml. The different lots of milk are weighed, and 1 ml is taken for each pound of milk in each lot and placed in the composite-sample jar. Any number of milliliters, or parts of milliliters, can be taken, in accordance with the amount of milk and the number of lots of milk to be sampled. Enough would have to be taken to obtain at least 40 ml, sufficient for a duplicate test.

Cylindrical sampling tubes should be used only when the milk is in cans with straight sides. The milk thief, the Scovell, and the McKay are the common sampling tubes. The first, which is most commonly used for milk, is a hollow copper tube about half an inch in diameter. When the tube is lowered into a can of milk, the milk

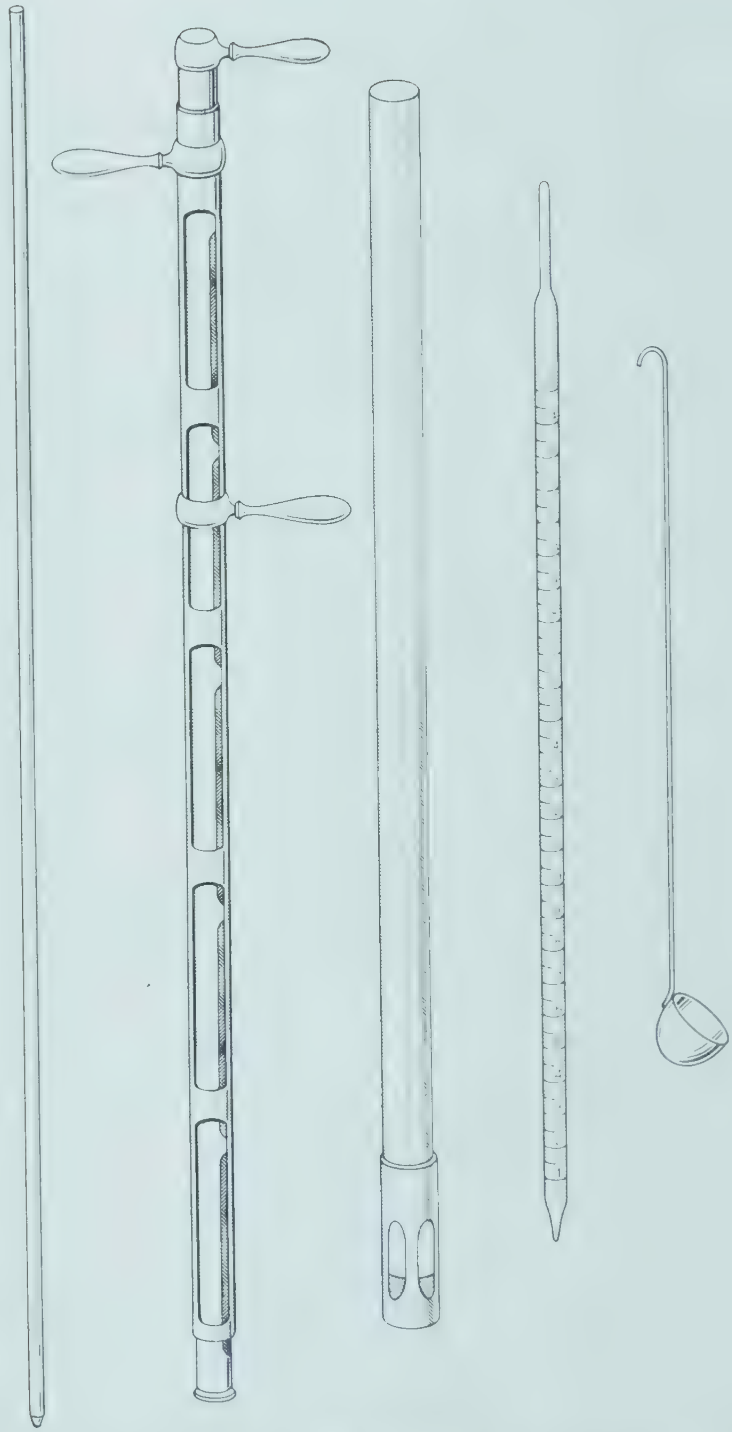

Fig. 52. Sampling equipment (1) milk thief; (2) McKay sampler; (3) Scovell sampler; (4) graduated pipette, 25 ml; (5) half-ounce dipper.

rushes up through the hole in the bottom of the tube until the latter touches the bottom of the can. The milk then stands at the same height in the tube as in the can. The thumb is placed over the top of the tube, and the milk in the tube, which is a narrow column proportionate to the total quantity of milk in the can, is placed in the composite-sample jar. Different lots of milk sampled must be in cans of the same diameter, in order that the same relation may exist between the width of the tube and the width of the can. Milk that has a heavy cream line on top must be mixed before sampling with the tube. This method is very simple, practical, and accurate and is used both in farm-record work and in the factory.

The half-ounce dipper, or one about this size, is commonly used in the milk plant. The same amount of milk is taken every day for 10 days or 2 weeks from each patron's milk and is placed in his composite-sample jar. This sample is not truly composite, but it is accurate enough for all practical purposes, because the amount of milk delivered by a patron from day to day, during a period of two weeks, is nearly the same.

The milk plant sometimes uses a device which, by means of vacuum and a hand operated valve, removes mechanically a sample from the weigh can and deposits it in the sample bottle.

The Composite-Sample Jar. A composite-sample jar should have (1) a capacity of a pint to a quart; (2) a large neck; (3) be easy to clean; (4) a tight-fitting stopper, easy to remove. For plant work, special bottles for the purpose are on the market. On the farm, an ordinary milk bottle may be used if it be kept stoppered, or, better still, a screw-top fruit jar may be employed.

Preservatives. If a composite sample is to be kept for two weeks, the milk must be preserved to prevent souring. The common preservatives used are bichloride of mercury, bichromate of potash, and formalin. Bichloride of mercury is used almost universally in the plant because it is very effective and is sold in convenient tablet form—one tablet for each sample. It has the disadvantage of being a deadly poison. For this reason the tablets are colored pink; thus the sample also is colored pink, and no one drinks pink milk. Such samples should be placed in properly labeled bottles or boxes and kept out of the reach of children. The preserved sample, after testing, should never be thrown out where any animal will have access to it.

Bichromate of potash is not so poisonous, and also now may be secured in tablet form. It gives the milk a light yellow color. Since

this preservative is not so effective as bichloride of mercury, excessive amounts must be used in hot weather. This large amount may lower the test slightly by making it more difficult for the acid to dissolve the casein when the sample is tested.

Formalin, easily secured at any drug store, is commonly used for preserving samples on the farm. It has a strong odor and is easily detected in the sample by this characteristic. The amount used does not make the sample appreciably poisonous. It is sold in liquid form and is not as easily handled as the tablets. Four to six drops will preserve a pint sample of milk for 2 weeks.

Care of Composite Samples. Composite samples should be arranged numerically on shelves or racks that are readily accessible. A little cupboard or rack which can be covered is desirable, because samples keep better when not exposed to strong light. Whenever fresh milk

Fig. 53. Composite sample jars on movable rack. The rack is run into the cooler when milk receiving is finished. (Courtesy Sealtest Foods Division, National Dairy Products Corp., Cleveland, Ohio.)

is added, the sample should be gently shaken, with a whirling motion, to mix the fresh milk with the preserved milk. The composite sample bottles always should be kept tightly stoppered. Otherwise moisture evaporation will cause high tests, particularly in the summer. In many milk plants, composite samples are kept on racks which are moved to cold rooms when the samples are not in use. Keeping the samples under refrigeration makes possible more accurate testing; evaporation is reduced and the milk does not become thick and lumpy. Refrigerated cabinets are also available for the storage of composite samples. Because cream has a tendency to stick to the sampling tube, to get thick or "leathery," and to be affected more by evaporation because of the high fat content, composite sampling of cream is not advisable. The large creameries test each shipment of cream daily, but composite samples are carried by a few small creameries receiving sweet cream.

Testing Composite Samples. Composite samples must be heated to about 90° F to facilitate mixing. In order to be thoroughly mixed, the sample must be poured back and forth. It then is pipetted and tested in the usual manner. It is advisable to use a little extra acid, because the preservative makes the curd more difficult to dissolve.

OPERATION OF THE TEST

Principles of the Babcock Test. When sulfuric acid and milk are mixed, the acid dissolves the solids-not-fat and leaves the butterfat free to rise. The heat of the reaction liquefies the butterfat and further facilitates separation. The acid also increases the difference between the weight of the butterfat and the solution, which enables centrifugal force to do its work more easily. The butterfat would never rise completely without the application of force, however. Centrifugal force, applied by whirling the bottles, works on the principle that when a fluid made up of parts having different weights is whirled, the heavier parts are thrown to the outside and the lighter drawn toward the center of force. Because butterfat is lighter than the other constituents, it is brought into the neck of the test bottle when the bottles are whirled in a centrifuge. In brief, the Babcock test is made possible by the chemical action of sulfuric acid and the application of centrifugal force.

Apparatus. THE MILK TEST BOTTLE. A test bottle having the neck graduated from 0 to 8 per cent, by 0.1 per cent divisions, is the one

Fig. 54. The 8 per cent milk test bottle.

in common use. One per cent on the bottle neck occupies a volume of 0.2 ml.

CREAM TEST BOTTLE. The three common types of cream test bottles are 50 per cent, 9-g, short neck; 50 per cent, 9-g, long neck; and 50 per cent, 18-g, long neck. The test bottles read 0 to 50 per cent by 0.5 per cent divisions.

THE SKIM MILK TEST BOTTLE. Since separator skim milk contains only 0.01 to 0.02 per cent butterfat, a neck of a very small diameter is required in order to read the butterfat accurately. This neck is so small that it would be impossible to pour the milk and acid into it; therefore, a double-necked bottle is required. The small neck of the bottle reads 0 to 0.25 or 0.05 per cent by 0.01 per cent divisions.

THE PIPETTE. The test is based on using an 18-g charge of milk. A pipette marked to hold 17.6 ml of milk is used. It has been found that it is much easier to measure milk into the test bottle than to weigh it. The charge delivered into the milk test bottle will be essentially the same even if the specific gravities are different.

$$17.5 \text{ ml} \times 1.030 = 18.03 \text{ g}$$

$$17.5 \text{ ml} \times 1.032 = 18.06 \text{ g}$$

$$17.5 \text{ ml} \times 1.034 = 18.10 \text{ g}$$

Fig. 55. Types of cream test bottles; (1) 9-g, 6-in. neck, 50 per cent; (2) 9-g, 9-in. neck, 50 per cent; (3) 18-g, 9-in. neck, 50 per cent.

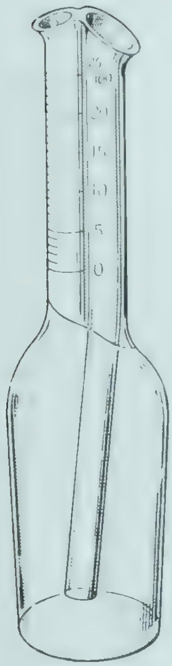

Fig. 56. The skim-milk test bottle.

The widest normal variation in weight would be 0.07 g and, calculated on the basis of 4 per cent butterfat milk, this amount would represent 0.015 per cent butterfat. The milk test bottles are not accurate enough, by graduations on neck to detect this small variation.

CREAM-TESTING SCALES. Sensibility reciprocal of 30 mg, that is, the addition of 30 mg to the scales, when loaded to capacity, shall cause a deflection of the pointer of at least one division on the graduation. Scales to weigh 1 to 12 bottles can be purchased. From the standpoint of accuracy, the single-bottle scales are the most satisfactory.

THE ACID MEASURE. An acid measure marked off to hold 17.5 ml of acid, the amount that is employed in the test, is used. For milk-test work on a small scale, the cylindrical acid measure is best. An automatic measure called the Swedish acid bottle or a graduated burette are convenient where considerable work is done, and a 17.5-ml glass dipper is very handy in cream testing.

THE ACID. Commercial sulfuric acid having a specific gravity of 1.82 to 1.83, equivalent to about 65°–66° Baumé, should be used. The strength of sulfuric acid can be tested by a specific gravity bulb made for the purpose, or by running trial tests and noting the color and clearness of the fat columns. This latter method is the prac-

Fig. 57. Single-bottle torsion balance. (Courtesy The Torsion Balance Co.)

tical one for farm use. If the acid proves to be too strong, it will weaken itself if the stopper is left out of the vessel containing it. The acid takes on moisture from the air. It is not wise to try to dilute the acid with water, but if this is done, the amount of water required should be ascertained and the acid poured into it. The water should never be poured into the acid, as it is lighter than the

Fig. 58. Electric Tester. Operator is reading a cream test.

acid and will float. Also, since the acid attacks the water and produces heat, an explosion may result. Care should be taken in handling the acid, as it eats into almost everything except glass and lead. If any acid is spilled on the hands or clothing, it should be washed off at once, soap powder or ammonia should be applied, and the hands or clothing washed again. This procedure will neutralize or check the action of the acid.

THE TESTER OR CENTRIFUGE. Small hand-operated machines up to the 12-bottle size can be purchased if a very small amount of testing is to be done, such as on a farm. For factory use, electrically driven testers holding 24 or 32 bottles are used.

DIVIDERS. Steel and brass dividers are on the market for this work. The prongs should open and close easily. Tests should not be read without them.

GLYMOL. Glymol, colored pink, may be purchased from dairy supply houses, or white mineral oil can be purchased from any drug store. It should be colored red with alkanet root. Some of the white mineral oil is placed in a wide-mouth bottle, a little cheese-

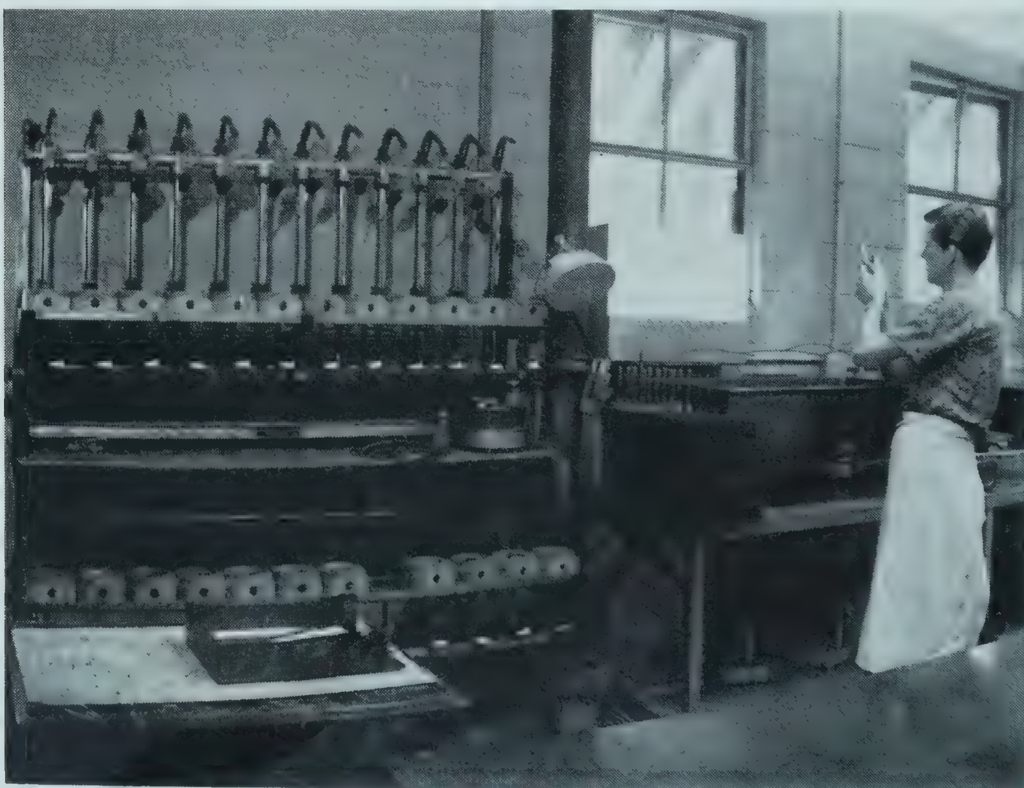

Fig. 59. Steps in the operation of the Babcock

cloth bag full of alkanet root is hung in the oil, and in a short time the oil is colored red.

THE DAIRY THERMOMETER AND THE WATER BATH. The most convenient water bath is one that has a rack for 24 test bottles and is the same height as the bottles. There is then no danger of running the bottles over by getting too much water in the tank.

Calibration of Glassware. Nearly every state has some law requiring that all glassware used in connection with the Babcock test be sent to the state experiment station to be tested for accuracy of graduation. This is known as the calibration of glassware. Most of the companies handling Babcock glassware keep a tested supply on hand, marked in accordance with the state laws of the territory covered by the organization in question.

Performing the Test. MILK. Many states have definite requirements for operating the Babcock test. The directions may differ somewhat from one state to another. Hence the reader should learn

test. (Courtesy W. K. Moseley Laboratory.)

the requirements for his state and follow them carefully when performing the test. Many states adhere to the official method for the Babcock test, as outlined by the Association of Official Agricultural Chemists, which is essentially as follows:

OUTLINE OF TEST. Measure 18 g of milk from a properly mixed sample into a standard milk-test bottle, by using a 17.6-ml standard pipette; add 17.5 ml of standard commercial sulfuric acid, and shake until all curd has disappeared. Continue the shaking for a few moments longer. The milk and acid, before mixing, should have a temperature of 60° to 70° F.

Whirl in the Babcock centrifuge for 5, 2, and 1 minutes, respectively, filling the bottle with hot soft water (temperature 160°F, or above) to the bottom of the neck after the first whirling, and to near the top graduation after the second whirling.

Set the test bottles into the water bath and read after a temperature of 135° to 140° F has been maintained for not less then 3 minutes. Read test by measuring the fat column from the bottom of the lower meniscus to the top of the upper meniscus. Use dividers for reading.

DETAILS OF TEST. The sample of milk is mixed by pouring it back and forth four or five times in an empty bottle. Half-pint milk bottles serve this purpose nicely. In pipetting the milk, one should hold up the sample bottle and pipette, so that the 17.6-ml mark on the pipette comes on a level with the eye. The forefinger should always be held over the end of the pipette, and the finger should be kept free from moisture so that the column of milk can be easily controlled. If the proper pipette is used, the tip can be inserted into the neck of the test bottle and the milk will run in easily. If the pipette is too large for this, bottle and pipette should be held at an angle of about 45°. The bottle should be turned slowly when the acid is first added, in order to clean the neck of the bottle of milk adhering to it. Acid and milk should be mixed by shaking with a smooth, rotary motion. When centrifuging, one must always be sure that the machine is well oiled and running at proper speed, and also that the machine is balanced, that is, the bottles placed opposite one another. The speed of some testers is taken with a spiral speed indicator. With most hand machines, the revolutions per minute of the crank are given on the machine and are counted off by the watch. When the crank speed is not given, find the diameter of the wheel holding the bottle pockets and refer to Table 28, which tells how fast this wheel must go. Then count the number of revolutions of the wheel for one turn of the crank, and divide this number into the

number of turns of wheel required. This figure will give the speed of the crank.

Various means of adding water to the tests have been devised. The best all-round method is to use a pint copper oil measure with snout drawn down to a fine point. The pipette or acid measure also can be used. On the power machine there are stationary hot-water tanks with rubber tubing connected. Great care must be taken not to run tests over at the last filling. The water in the bath should come up around the butterfat in the necks of the bottles. The object of using the bath is to allow the readings to be taken always at the same temperature no matter where they are made. They will then be accurate and comparable. Cold causes the butterfat to contract, and heat causes it to expand. Hence, if some tests were run in a hand machine in a cool room, not only would they read low, but the butterfat probably would be solidified when the tests were taken from the machine. It is much more important to use the bath for hand machines than for steam machines, although it is recommended for both in order to have the temperature at a definite point. In reading the tests, one prong of the divider is placed at the bottom of

Fig. 60. Adding acid to milk which has been pipetted into test bottle. (Courtesy Purdue Experiment Station.)

the butterfat column and the other at the top of the meniscus at the top of the column. Without moving the prongs, the lower one is placed on the zero mark, and the percentage of butterfat read directly from the bottle. The reason for including the meniscus in the reading is to offset about 0.2 per cent butterfat that stays down in the mixture in the base of the bottle in spite of the whirling. The meniscus amounts to about 0.2 per cent.

TABLE 28. SHOWING RELATION OF DIAMETER OF WHEEL TO SPEED OF TESTER[a]

Diameter of Wheel, inches	Revolutions of Wheel, per minute	Diameter of Wheel, inches	Revolutions of Wheel, per minute
10	1,074	18	800
12	980	20	759
14	909	22	724
16	848	24	693

[a] E. H. Farrington and F. W. Woll, *Testing Milk and Its Products*, Mendota Book Company, Madison, Wisconsin.

CREAM. Cream samples should be tested as soon as possible and not later than three days after they are taken. Composite samples, representing portions of consecutive deliveries of the same patron, are unreliable. Samples should at all times be kept in nonabsorptive containers, sealed air-tight and held in the cold.

Immediately before testing, mix the sample until it pours readily and a uniform emulsion is secured. If in good condition, shake, pour or stir until properly mixed. If very thick, warm to 85° F, and then mix. In case of lumps of butter, heat the sample to 100° to 120° F by setting in water bath, mix thoroughly, and weigh out at once. For commercial work on a large scale, it is advisable to temper all samples to 100° to 120° F in a water bath previous to mixing. Great care should be exercised to avoid over-heating the sample, which might cause the cream to "oil off." This precaution is especially necessary with thin cream.

Weigh 9 g or 18 g, respectively, of the properly mixed sample into a standard cream-test bottle on standard cream-testing scales which are in proper working condition, set level, and protected from drafts.

Method I. Add 9 ml of water after the cream has been weighed into the test bottle and before the acid is added, then add 17.5 ml of

Fig. 61. Weighing out cream. (Courtesy Chase, Ltd. Photo, Washington, D.C.)

acid. Whirl in standard Babcock centrifuge at proper speed, 5, 2, and one minutes, respectively, filling the bottles with hot, soft water, temperature 160° F or above, to the bottom of the neck after the first whirling and to near the top graduation after second whirling.

Method II. Add 8 to 12 ml of acid in the case of the 9-g bottle or 14 to 17 ml of acid in the case of the 18-g bottle, or add acid until the mixture of cream and acid, after shaking, has a chocolate brown color. After the cream and acid have been thoroughly mixed and all lumps have completely disappeared, add a few milliliters (not less than 5 ml) of hot, soft water, whirl 5 minutes, add hot, soft water to near top of scale, and whirl one minute.

The proper speed of the centrifuge is 800 revolutions per minute for an 18-in. diameter wheel and 1,000 revolutions per minute for a 12-in. diameter wheel.

Set the test bottles into water bath and after a temperature of 135° to 140° F has been maintained for not less than three minutes, add a few drops of glymol and read at once, preferably using dividers. Experienced testers are able to make correct readings

without glymol by reading to the bottom of the upper meniscus, but the use of glymol is urged.

Cream must be weighed into the test bottle because (1) it sticks to the pipette so much more than milk, and (2) it is so much lighter than milk that, even if it did not stick to the pipette, the latter would not deliver the required amount by weight into the test bottle. In weighing out the cream, the scales with empty bottles are balanced. A 9-g weight is placed on one side and cream is pipetted into the bottle on the other side until the scales balance. The weight is removed and cream is pipetted into the other bottle until the scales again balance, and so on, depending on the number of bottles weighed out at once. Care must be taken not to change bottles from one side of the scale to the other, as bottles are not all of the same

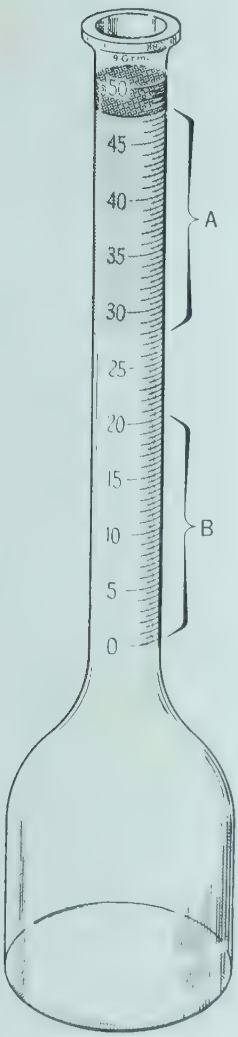

Fig. 62. Measuring the cream test. Note that glymol has been added to level the meniscus.

weight. If cream is spilled on outside of bottle, wipe clean before proceeding.

Cream tests are read to the bottom of the meniscus because impurities that get into the butterfat column offset the butterfat that stays down in the base of the bottle. The glymol greatly facilitates the reading by leveling the meniscus. The tendency is to read about a half per cent too high when glymol is not used. The glymol can best be added by dropping it from a glass tube and letting it run down the neck of the bottle. It should not be dropped directly on the butterfat, nor should it be added until just before the tests are read. If these directions are followed, the glymol will not mix with the butterfat.

SKIM MILK. The test for skim milk is carried out in the same manner as for whole milk with two or three exceptions. About 20 ml of acid are used, because of the extra solids-not-fat in skim milk. It is best to add about two-thirds of the acid, shake until the curd is dissolved, and then add the rest of the acid and shake again. This allows more room in the bottle for the first shaking, and the milk and acid are less likely to blow out the neck of the bottle. The graduated neck of the bottle should be held away from the operator while mixing milk and acid. The tests are whirled 10, 3, and 2 minutes to insure getting out all the fat that is possible by this method. The remaining steps are the same as for whole milk. It will not be necessary to use dividers when reading the test; simply press on top of either neck of the bottle with the finger, thereby forcing the butterfat column to rest between the graduations. Great care must be taken to have all glassware absolutely free from grease, as a trace of butterfat sticking to the glass will raise the test considerably.

BUTTERMILK AND WHEY. Buttermilk is the product left after butter is churned out of cream. It has essentially the same composition as skim milk and is tested in the same way. Buttermilk frequently has over 0.25 per cent butterfat in it, and it is always wise to make a duplicate test, making one in a skim-milk test bottle and the other in a whole-milk test bottle. Because of the fact that the gravimetric method results tend to show that the Babcock test gives low results, the American Association* method (given in Appendix F) was suggested. The results by this latter method compare very closely with those of the gravimetric, but recent investigations by Thurston and Petersen show that both the gravimetric and the American Association methods give results that are too high, primarily because they

* American Association of Creamery Butter Manufacturers.

include the lecithin content along with the fat. The Minnesota test for buttermilk, which is in frequent use, is given in Appendix F.

Whey is obtained in the process of cheesemaking and is tested in the same way as buttermilk, except that 17.5 ml of acid are used.

MISCELLANEOUS DAIRY PRODUCTS. The Babcock test modified in a variety of ways may be used to approximate the butterfat in various manufactured dairy products. Methods are described in Appendix F.

Cleaning Glassware. When the test bottles are emptied they should be shaken up and down, as this helps to clean them. The dissolving power of the acid is not entirely used up, and if bottles are emptied into a sink it must be lined with lead and the pipe connecting the sink to the sewer must also be lead lined. When only one or two tests are made at once, it is a good plan to place a wooden cover, with several holes bored in it, over a crock, and place the bottle necks in these holes for draining. Jars of waste acid should be emptied on the ground where livestock, such as poultry, will not get at the waste. A stone crock is frequently used to hold waste acid. The best way to handle a number of bottles is to make a rack holding a dozen bottles. Slide a wooden retainer over the necks of the bottles, so that the whole dozen can be tipped over, dumped, washed, and rinsed at once. After the acid runs out, rinse bottles out in warm water, then use detergent and water. It is best to have a tank of strong detergent solution in which to sink the bottles. If a tank is not available, shake some detergent into each bottle, pour in hot water, and shake vigorously. Brush out the necks with a special bottle brush, empty, and rinse in clear, hot water. When some sediment sticks to the bottle, a little acid should be added to remove it; the bottle is then rinsed out. Remember that glassware is easier to wash if it is cleaned immediately after use. Never let it stand around in a dirty condition. Always be sure that glassware is free from grease before making a test, or the test will not be accurate.

Defective Tests. The following characteristics are desired in an ideal, accurate Babcock test:

1. The butterfat column should
   (*a*) Be straw yellow in color.
   (*b*) Be free from specks and sediment.
   (*c*) Have sharp, well defined upper and lower meniscuses.
   (*d*) Be within the graduations on the neck of the test bottle.
   (*e*) Be at a temperature of 135° to 140° F when read.

2. The water immediately below the butterfat column should be clear.

Defective tests may (1) show a charred or burnt butterfat column or (2) a curdy butterfat column. The causes of black butterfat columns, with charred, flaky material at the base, are too warm milk or acid, too strong acid, too much acid, or a rough, shaking motion rather than a smooth, rotary motion. This black, flaky material, a mixture of burned milk sugar (lactose) and butterfat, makes an accurate reading impossible. The causes of curdy butterfat columns, with white sediment at the base, are too cold milk or acid, too weak acid, not enough acid, or insufficient mixing of milk and acid. This sediment, which is undissolved solids-not-fat, makes an accurate reading impossible. The remedies for the above troubles can easily be read in the causes. The appearance of the butterfat column is really the guide as to the amount of acid to use. In hot weather, when both milk and acid are about 90° F, best results may be obtained by using a little over a half-measure of acid. The amount under proper conditions is 17.5 ml, but this must be varied to suit the conditions under which one is working. Another defect, caused by hard water, is the presence of bubbles on top of the butterfat column, which make an accurate reading difficult. This difficulty can be overcome if the hard water is boiled, or if a few drops of sulfuric acid are added to the water to be used.

QUESTIONS

1. When, where and by whom was the Babcock test invented?
2. What is the application of the Babcock test in buying milk for bottling purposes?
3. What is meant by buying milk or cream on a straight butterfat basis?
4. How is the price of a 40-qt can of cream commonly determined?
5. What is the application of the Babcock test in upgrading the dairy herd?
6. How is the Babcock test used for detecting added water to milk?
7. What is meant by standardizing milk or cream?
8. What is the application of the Babcock test in the sales end of the fluid milk business?
9. What is meant by butterfat accounting?
10. Why is butterfat cost analysis so important?
11. Why must so much care be taken in obtaining a correct sample for the Babcock test?

12. How would you sample freshly drawn milk? Cold canned milk? A bottle of milk?
13. How is milk handled in the plant receiving room when it is bought on weight and test?
14. What precaution must be taken in sampling bulk tank milk?
15. What is partially churned milk, and what precautions must be taken to get even an approximate sample?
16. How would you sample frozen milk or cream?
17. How would you sample sour milk or cream?
18. What is a composite sample?
19. What are some of the common uses of the composite sample?
20. What are four general methods of taking composite samples?
21. What are the essential factors of the composite sample jar?
22. What preservatives are used in composite samples and why are precautions necessary in their use?
23. How should composite samples be cared for?
24. What extra precaution needs to be taken when testing composite samples?
25. The Babcock test depends upon what chemical and mechanical actions?
26. How much milk is used in making the Babcock test?
27. How do the gradations on the neck of the cream test bottle differ from those on the milk test bottle?
28. Why is a double neck necessary on the skim milk test bottle?
29. Why is a 17.6-ml pipette used in connection with the butterfat test for milk?
30. Why is cream weighed into the test bottle?
31. Why is commercial sulfuric acid used in the test?
32. Why should water never be poured into sulfuric acid?
33. What should you do if you should spill some sulfuric acid on your skin or clothing?
34. What are the various sizes and types of centrifuges used?
35. What is meant by the calibration of glassware and where is this work done?
36. Outline step by step the operation of the Babcock test for milk.
37. What is meant by the meniscus?
38. List all of the things you can think of that might make the butterfat test for milk inaccurate?
39. How does the butterfat test for cream differ from that for milk? Give reasons.
40. What are the differences in testing milk and skim milk or buttermilk?
41. Why is clean glassware so important and how is it cleaned?
42. List the causes of defective tests.

PROBLEMS

1. How much time would be saved in 30 days in the case of 300 patrons, if testing were done twice a month instead of every day, if it takes 45 minutes to make 24 tests? *Ans.* 262.5 hours

2. One cow in a herd gave, in the morning, 20 lb of milk testing 3.7 per cent, and at night 17 lb, testing 3.5 per cent. What was the total weight of the butterfat for that day? What was the average percentage of butterfat for that day? One qt of milk equals 2.15 lb. What would have been the receipts to the owner if the milk had been sold for 5 cents a qt? If butterfat sold for 35 cents per lb?
Ans. 1.335 lb butterfat
3.60 per cent average test
86 cents if sold by qt
46.72 cents if sold by butterfat

3. What would be the average test of the following lots of milk: 400 lb, testing 3 per cent; 100 lb, testing 4.5 per cent; 600 lb, testing 5 per cent; 800 lb, testing 2.8 per cent; 1,500 lb, testing 3.2 per cent; 60 lb, testing 6 per cent? *Ans.* 3.48 per cent

4. A patron averages a delivery of 250 lb of milk daily for the month of April. He receives $1.85 per cwt, plus or minus 5 cents per cwt for each tenth of 1 per cent variation in butterfat from 3.7 per cent. The three composite samples tested 3.6, 3.9, and 3.8 per cent. What does the patron receive for his milk for the month? *Ans.* $142.50

5. Find average test of 200 lb milk, testing 3 per cent; 400 lb skim milk, testing 0.2 per cent; and 500 lb milk, testing 6 per cent.
Ans. 3.34 per cent

6 A plant has 6,000 lb of 3.8 per cent butterfat milk on hand at close of business March 31st and 3,000 lb of 3.7 per cent butterfat milk on hand at close of business April 30th. During April the plant bought 3,028,350 lb of milk, testing 3.9 per cent butterfat. The plant had a butterfat loss of 1.2 per cent. How many pounds of butterfat were lost? *Ans.* 1,418.55 lb

7. What is the value of the butterfat in 5,000 lb of 4 per cent milk when 30 per cent cream (8.3 lb to a gal) is worth $1.40 per gal?
Ans. $112.44

8. If it costs a man $78.00 per year, on the average, to keep his cows, how much milk containing 5 per cent butterfat must they average per year to pay for their keep, if their owner sells butterfat at 32 cents per lb? *Ans.* 4,875 lb

9. Find the number of pounds of 3.5 per cent milk and 35 per cent cream that must be mixed to make 1,000 lb of 20 per cent cream.
Ans. 476.1 lb milk; 523.9 lb cream

10. A man has 1,000 lb of skim milk on hand. How much skim milk will he have left after he reduces the butterfat content of 600 lb of 32 per cent cream to 25 per cent? *Ans.* 832 lb

11. Compute the pounds of butterfat in the following:

Whole milk	82 lb	testing	3.80	per cent butterfat
Cream	80 lb	testing	39.00	per cent butterfat
Cream	80 lb	testing	40.00	per cent butterfat
Cream	83 lb	testing	20.00	per cent butterfat
Buttermilk	85 lb	testing	0.12	per cent butterfat
Skim milk	84 lb	testing	0.03	per cent butterfat
Whey	85 lb	testing	0.32	per cent butterfat

Ans. 83.3102 lb

12. If an error of 2 per cent had been made in measuring the butterfat column in testing some 35 per cent cream, that is, if it had been read as 33 per cent, how much money would a man lose in a year in delivering 5,000 lb of 35 per cent cream, if the average price of butterfat were 35 cents per lb? *Ans.* $35.00

13. How many pounds of 40 per cent cream and 22 per cent cream must be mixed together to produce 94 lb of 38 per cent cream?
Ans. 10.44 lb 22 per cent cream, 83.56 lb 40 per cent cream

14. One thousand pounds of milk are separated, and 105 lb of 35 per cent cream and 895 lb of 0.05 per cent skim milk result. What did the milk test? *Ans.* 3.71 per cent

15. How many pounds more of 18 per cent cream than 25 per cent cream can be taken from 1,500 lb of 5 per cent milk? *Ans.* 116.66 lb

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CHAPTER **13**

Testing Milk for Total Solids

The Importance of the Total Solids Test. Almost every state in the union, as well as the federal government, has standards defining lawful milk.* These standards have been adopted to protect the public against milk of low butterfat and solids content brought about by watering or skimming the milk, and against milk from very low-testing cows. When a producer's milk tests abnormally low in butterfat, a milk company also will wish to run a test for adulteration. Before the invention of the Babcock test and in the absence of any simple test for determining the total solids content of milk, adulteration was very commonly practiced; today it is not common.

The milk standard is usually stated in terms of per cent butterfat, per cent S.N.F. and per cent T.S. The Federal requirements are 3.25 per cent butterfat, 8.5 per cent S.N.F., and 11.75 per cent T.S. The federal standard applies only to milk sold in the District of Columbia and milk shipped from one state to another. For example, 3 per cent milk is legal in New York State, but if a New York farmer ships milk into Massachusetts it must not only come up to the federal standard but also to the Massachusetts standard, which in this case happens to be higher than the federal standard.

The enforcement of these state standards usually rests with the state board of health, the state board of agriculture, or a dairy and food commission. City milk inspectors also enforce standards for the cities. In general, inspectors are hired to travel about the state, picking up samples from milk trucks, trains, stores, and so on. These samples are taken to laboratories and tested, and if they are

* See Appendix J for standards.

found to be below the standard, a warning is issued. If a sample taken after the warning shows no improvement, the offender is taken into court.

Methods of Determining the Total Solids in Milk. The only absolutely reliable method, and the one that is likely to stand in court, is the gravimetric test. In brief, this test involves weighing out a small sample of the milk into a small dish on a chemical balance and then evaporating the moisture in an oven or over a hot-water bath, until trial weights show that the residue has reached constant weight. The percentage of total solids is then calculated. Incidentally, this is the only method that can be used for determining the total solids in milk products, such as cream, milk powder, ice cream, etc.

For making approximate tests on milk, there is an instrument on the market known as the lactometer. From the lactometer reading and the percentage of butterfat, the percentage of S.N.F. or T.S. can be calculated with the aid of a formula.

Principle Upon Which the Lactometer Operates. The use of the lactometer rests on the principle that a body floating in a liquid displaces an amount of the liquid equal to the weight of the floating body. In other words, if a glass cylinder is filled to the brim with milk and the lactometer is floated in it, the weight of the milk that runs over is equal to the weight of the lactometer.

Description of the Instrument. Two types of lactometers will be described. Until 1956, the Quevenne lactometer was the one in common use. At the bottom of the Quevenne is a large bulb filled with shot or mercury to keep the lactometer in an upright position when floating. Just above this is the bulb of a thermometer, the paper scale for which is located at the top of the instrument. Above this bulb is a large air chamber for floating the lactometer, and just above this air chamber is a paper lactometer scale, reading in lactometer degrees from 15 at the top down to 40.

In April 1956, Paul D. Watson of the Eastern Utilization Research Branch of the U.S. Department of Agriculture published his findings with a modified Quevenne lactometer, designed to give more accurate results. This instrument works on the same principle and reads to 0.2 of a degree.

Common Factors Affecting the Weight of a Given Volume of Milk.

TEMPERATURE. Heat causes milk to expand, and thus makes a given

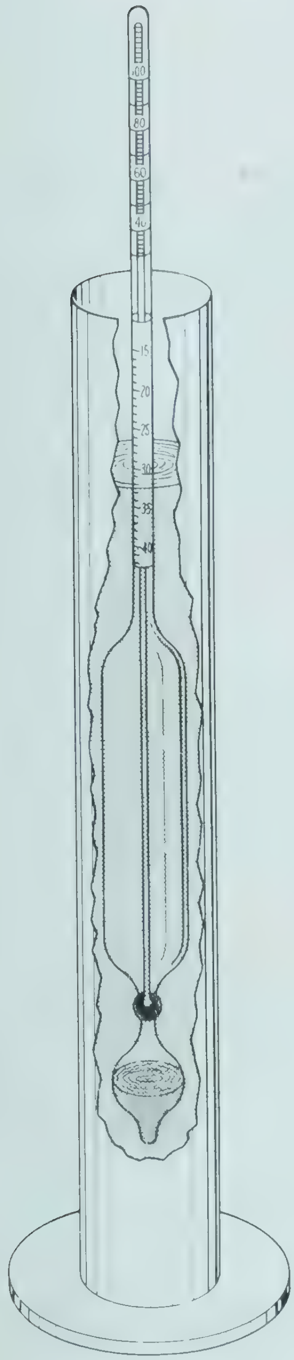

Fig. 63. Quevenne lactometer showing method of obtaining reading.

volume of it weigh less. Cold, on the other hand, causes the milk to contract and makes a given volume weigh more. This difference is plainly shown on the farm when milk is cooled. A can of warm night's milk, put into the cooling tank at night, is no longer full in the morning and has to be "topped out" before shipping.

THE PERCENTAGE OF TOTAL SOLIDS NORMALLY PRESENT IN MILK. With the increase of the percentage of butterfat in milk the solids-not-fat also increase, so that a quart of 5 per cent milk, for example, will weigh slightly more than a quart of 3 per cent milk.

ADDITION OF WATER. Water is lighter than milk, and therefore a given volume of milk weighs less if it contains some extraneous water.

THE ADDITION OF SKIM MILK OR THE REMOVAL OF CREAM. Skim milk is heavier than milk; hence, the addition of skim milk to milk, or the removal of some of the cream, increases the weight of a given volume of milk.

Operation of the Test when Using the Quevenne Lactometer. The sample must be representative and must be thoroughly mixed as for the Babcock test. The temperature of the milk must be between 50° and 70° F. A glass cylinder is filled with the milk and set in some receptacle, such as a sink or a pan. The lactometer is then slowly lowered into it.

In a few seconds the lactometer becomes stationary, and the lactometer scale is read at the point to which the milk rises on the lactometer scale (the meniscus formed by the milk on the lactometer scale is included). This reading is recorded, and the temperature noted and recorded. Because temperature affects the weight of a given volume of milk and hence the lactometer reading, obviously the readings must be taken at some definite temperature, or must be corrected to that temperature. The lactometer gives a correct reading directly only when the milk is at 60° F. If the milk is some other temperature between 50° and 70° F, a correction factor can be used to give a corrected reading. This factor is 0.1 of a lactometer degree added to the lactometer reading for each degree of temperature above 60° F, and subtracted for each degree below 60° F. Thus, if the lactometer reads 30 at 68° F, the correct reading is 30.8; and if it reads 29.5 at 53° F, the correct reading is 28.8. The lower the correction factor used, that is, the nearer the temperature is to 60° F, the more accurate the results will be.

The operation of the modified lactometer is the same except the milk must be at a temperature of 102° F $\pm$ 2° F. For each degree above 102° F add 0.2 to the reading, and for each degree below 102° F, subtract 0.2. The lactometer should be warmed to 102° F before use, and the milk temperature should be checked with an accurate thermometer.

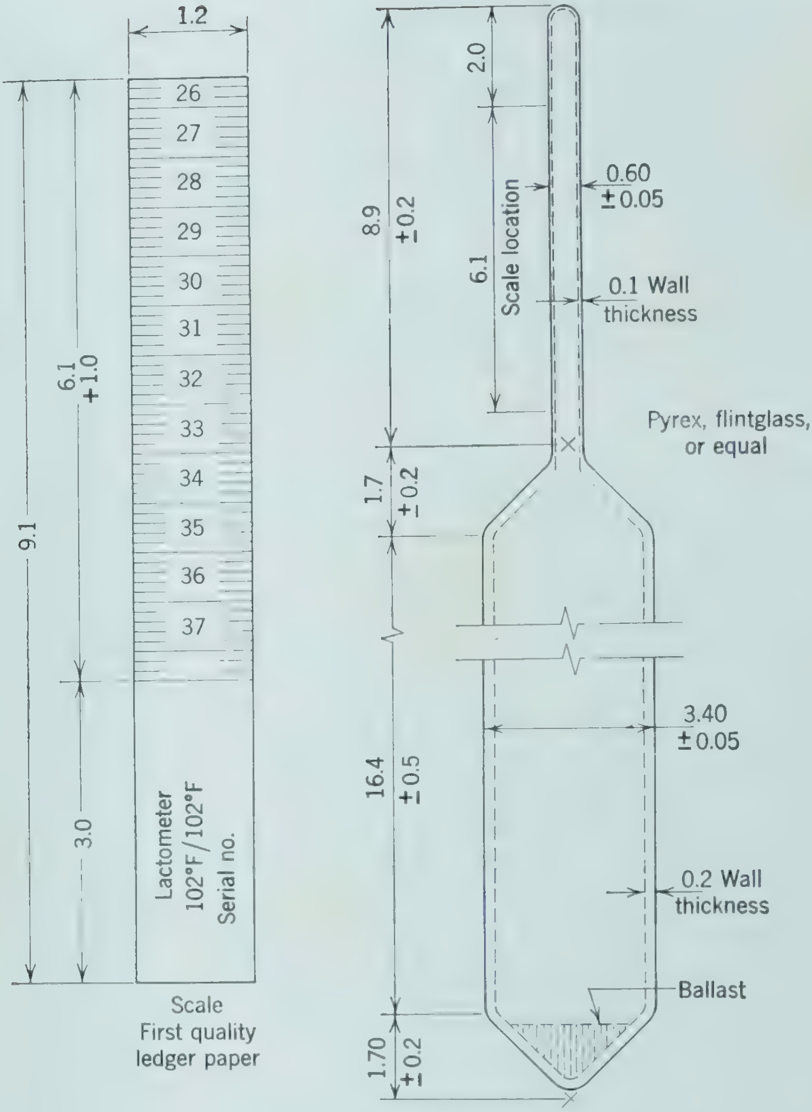

Fig. 64. Modified lactometer, U.S.D.A. Bulletin ARS-73-10. (Degrees are in centimeters.)

Calculation of the Specific Gravity of Milk. The rule is to divide the Quevenne lactometer reading by 1,000, multiply by 100, and add 1 to the result. Thus if the lactometer reading at 60° F is 32, 32 $\div$ 1,000 equals 0.0032 $\times$ 100 $=$ 0.032 $+$ 1 equals 1.032 specific gravity.

Calculation of the Per Cent S.N.F. and T.S. in Milk. To find the solids in milk, both lactometer and Babcock tests must be made and this formula must be used with the Quevenne lactometer:

$$\tfrac{1}{4} L + (0.2 \times \text{per cent butterfat}) = \text{per cent S.N.F.}$$

L is the corrected lactometer reading in degrees. For example, if the lactometer reading is 32.5 at 55° F, and butterfat test is 3.9 per cent, find the per cent S.N.F. and T.S.

$$\text{Correct } L = 32$$

$$\tfrac{1}{4} \text{ of } 32 = 8$$

$$0.2 \times 3.9 = 0.78$$

$$8 + 0.78 = 8.78 \text{ per cent S.N.F.}$$

$$\text{Per cent T.S.} = 8.78 + 3.9 = 12.68 \text{ per cent}$$

With the modified lactometer, use the following equation:

$$\text{Total solids (per cent)} = 1.33\ F + \frac{273\ L}{L + 1{,}000} \text{ minus } 0.40$$

$$F = \text{percentage of butterfat by Babcock method}$$

$$L = \text{lactometer reading in degrees}$$

The solids-not-fat may be found by using 0.33 F instead of 1.33 F, or by subtraction of the butterfat percentage from the total solids percentage. The total solids of skim milk samples may be calculated by dropping the constant (—0.40) from the formula.

How to Identify Adulterated Milk. In identifying adulterated samples, it must be remembered that adding water to milk lowers both the percentage of butterfat and of S.N.F., whereas adding skim milk or removing cream lowers the butterfat, but raises the S.N.F.; adding both water and skim milk lowers the butterfat, but may leave the S.N.F. normal. It is also necessary to know the normal relation between the percentage of butterfat and solids in milk as it comes from the cow. This relationship is shown in Table 29, representing an analysis of over 250,000 samples of milk.

An understanding of the method of using this table can best be gained by taking a few examples. Suppose the percentage of butterfat and S.N.F. is as follows in a number of samples, what is wrong with the samples?

1. Per cent butterfat 2.5, S.N.F. 9.02.
2. Per cent butterfat 2.8, S.N.F. 7.90.
3. Per cent butterfat 3.9, S.N.F. 8.75.
4. Per cent butterfat 3.5, S.N.F. 8.00.
5. Per cent butterfat 3.0, S.N.F. 8.65.

Note that number 1 has a S.N.F. content of 9.02 and a butterfat test of 2.5 per cent. A glance at the table shows that milk testing 9.02 per cent S.N.F. should test nearly 5 per cent butterfat; therefore (1) must be skimmed, because the S.N.F. content is far too high for the butterfat test of 2.5 per cent; number 2 is watered, or else it is milk from a very low-testing cow; it does not matter which, as both the per cent of butterfat and S.N.F. are below standard; 3 is normal milk, because the table shows that the natural relation exists between the percentage of butterfat and S.N.F.; 4 is watered, because the percentage of S.N.F. is considerably lower than it should be for 3.5 per cent milk; 5 appears to be both watered and skimmed, as the butterfat test is too low for the S.N.F. content, which is that stated for 3.6 per cent milk.

Another thing to remember, especially in passing judgment on a sample like 5, is that water is lighter than milk in greater degree than skim milk is heavier, so that a little water added to milk lowers the S.N.F. content much faster than a like amount of skim milk raises it. The S.N.F. content of water is, of course, zero, whereas that of skim milk is 9 to 9.5 per cent. Since the normal solids-not-fat content of milk is approximately twice the butterfat content, obviously adding water to milk will lower the S.N.F. test about twice as fast as that of the butterfat. Suppose, for example, that 5 had tested 4 per cent butterfat and 8.79 per cent S.N.F. before it was tampered with; it is plain that 1 part of either water or skim milk mixed with 3 parts of the milk would have reduced the butterfat to 3 per cent, a reduction of 1 percentage point. If water alone had been used, the S.N.F. test would have been reduced about 2 percentage points, leaving a S.N.F. content of about 6.7 per cent. If skim milk alone had been used, the S.N.F. content would have been raised from 8.79 to about 8.96, calculated as follows:

$$
\begin{array}{llll}
300 \times 0.0879 & = & 26.37 & \text{lb S.N.F. in 300 lb 4 per cent milk} \\
100 \times 0.095 & = & 9.5 & \text{lb S.N.F. in 100 lb skim milk} \\
\hline
400 & \text{Total} & 35.87 &
\end{array}
$$

$$35.87 \div 400 \times 100 = 8.96 \text{ per cent S.N.F. in 400 lb 3 per cent milk.}$$

Although water in the above problem would lower the S.N.F. test 2 percentage points, a like amount of skim milk would raise the S.N.F. test about 0.2 percentage points. Hence it can be seen that it must have been a certain combination of skim milk and water that brought about the tests in 5.

It should be understood that Table 29 can be used only as a guide, and some leeway must be allowed. For example, a sample of milk

might test 3.5 per cent butterfat and 8.79 per cent S.N.F. or 4 per cent butterfat and 8.66 per cent S.N.F. As long as the samples are above the local standard, there is no cause for anxiety, even though the relation between the percentages of butterfat and solids-not-fat are not always the same as in Table 29. Frequently when milk is watered or skimmed, such a great change is produced there

TABLE 29. RELATION OF BUTTERFAT TO OTHER SOLIDS IN MILK[a]

Fat	Solids-Not-Fat	Total Solids	Ratio Fat to Solids-Not-Fat
3.0	8.33	11.33	1:2.77
3.1	8.40	11.50	1:2.71
3.2	8.46	11.66	1:2.64
3.3	8.52	11.82	1:2.58
3.4	8.55	11.95	1:2.52
3.5	8.60	12.10	1:2.46
3.6	8.65	12.25	1:2.40
3.7	8.69	12.39	1:2.35
3.8	8.72	12.52	1:2.30
3.9	8.76	12.66	1:2.25
4.0	8.79	12.79	1:2.20
4.1	8.82	12.92	1:2.15
4.2	8.86	13.06	1:2.11
4.3	8.89	13.19	1:2.07
4.4	8.92	13.32	1:2.03
4.5	8.95	13.45	1:1.99
4.6	8.98	13.58	1:1.95
4.7	9.01	13.71	1:1.92
4.8	9.04	13.84	1:1.88
4.9	9.07	13.97	1:1.85
5.0	9.10	14.10	1:1.82

[a] Reprinted by permission from Kelly and Clement's Market Milk, John Wiley and Sons, New York.

is little difficulty in detecting it with the lactometer and Babcock test. Other methods must be used to detect marginal cases.

Detection of Adulterated Milk by the Cryoscope and Immersion Refractometer. Methods for the detection of added water in milk by the use of the Hortvett and Fiske cryoscopes and Zeiss immersion refractometer are given in "Standard Methods of Milk Analysis."*

The freezing point of normal milk is very constant and is usually

* Published by the American Public Health Association.

—0.55° C. If the milk is watered, the freezing point is raised towards 0° C, which is the freezing point of water. By the use of the Hortvett cryoscope, equipped with a very sensitive thermometer, the freezing point of the milk can be accurately determined. From this result, the percentage of added water can be calculated easily. By this method as little as 3 per cent added water can be detected accurately.

The serum of milk has the ability to deflect a ray of light passing through it. If the milk is watered, the extent to which it will deflect or "bend" light rays is changed. The Zeiss immersion refractometer is an instrument for measuring the "refractive index," which is the ability of a liquid to deflect light rays. Normal milk serum, which has been prepared in one of the official procedures for the refractometer has a known refractive index. If the refractometer reading of the serum, prepared from a suspected sample, is lower than the reading for normal milk, it is evident that water has been added to the milk.

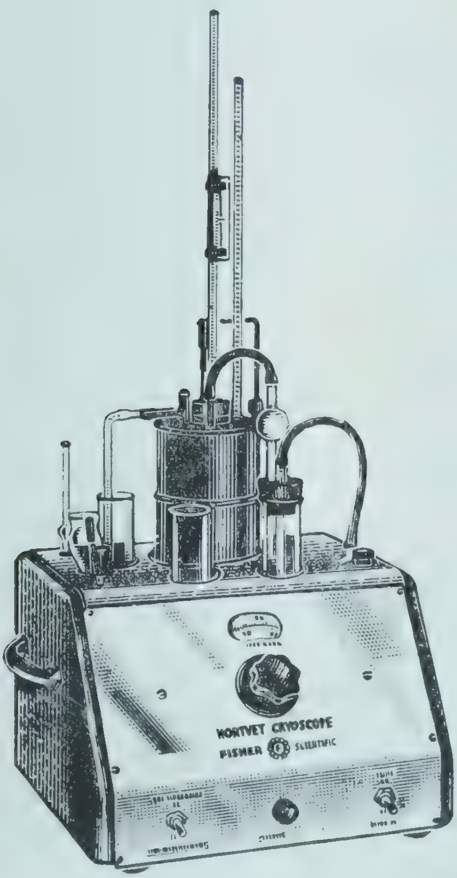

Fig. 65. Hortvett cryoscope for determining the freezing point of milk. (Courtesy of Eimer and Amend.)

QUESTIONS

1. What is the importance of the total solids test (*a*) to the milk dealer? (*b*) To the public?
2. What are the federal standards for milk and in what area do they apply?
3. What are some of the state enforcement agencies?
4. What is the gravimetric test for total solids?
5. Upon what principle does the lactometer operate?
6. What are the differences in the two types of lactometers described in the text?
7. What are the common factors affecting the weight of a given volume of milk?
8. Outline step by step the operation of the Quevenne lactometer.
9. How is the specific gravity of milk calculated?
10. What factors must be understood in identifying adulterated samples of milk?
11. If a certain amount of water is added to a sample of milk and the same amount of skim milk is added to another sample, which sample will have its S.N.F. content affected the most?
12. What is the cryoscope?
13. What is meant by refractive index?

PROBLEMS

1. Find the per cent S.N.F. and T.S. in the following samples and state what you think is the condition of the samples.

No.	Lactometer Reading	Temperatures	Per Cent Butterfat
1	28	62	4.5
2	25	65	2.7
3	33.5	58	3.0
4	32	61	3.85
5	28.5	62	3.1

Ans.	Per Cent S.N.F.	Per Cent T.S.
1	7.95	12.450
2	6.915	9.615
3	8.925	11.925
4	8.795	12.645
5	7.795	10.895

2. The Quevenne lactometer reading in a sample of milk at 66° F is 31. What is the specific gravity of the milk? *Ans.* 1.0316

3. Find the specific gravity, S.N.F. and T.S. in a sample of milk testing 3 per cent butterfat and having a lactometer reading of 33.8 at 56° F.
Ans. 1.0334 specific gravity
8.95 per cent S.N.F.
11.95 per cent T.S.

4. Find the specific gravity, S.N.F. and T. S. in a sample of milk testing 3.9 per cent butterfat and having a lactometer reading of 31.8 at 63° F.
Ans. 1.0321 specific gravity
8.805 per cent S.N.F.
12.705 per cent T.S.

5. If the modified lactometer reading is 32 at 102° F and the butterfat test is 4 per cent, what is the percentage of T.S. *Ans.* 13.78

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CHAPTER 14

Quality Tests for Milk

High-quality milk should possess the following characteristics:

1. Free from all pathogenic microorganisms.
2. A low total microorganism count.
3. Free from sediment and extraneous matter.
4. Slightly sweet taste and a mild aromatic flavor and aroma, free from off-flavors.
5. Meet state and/or federal standards for the minimum butterfat, solids-not-fat and total solids content.

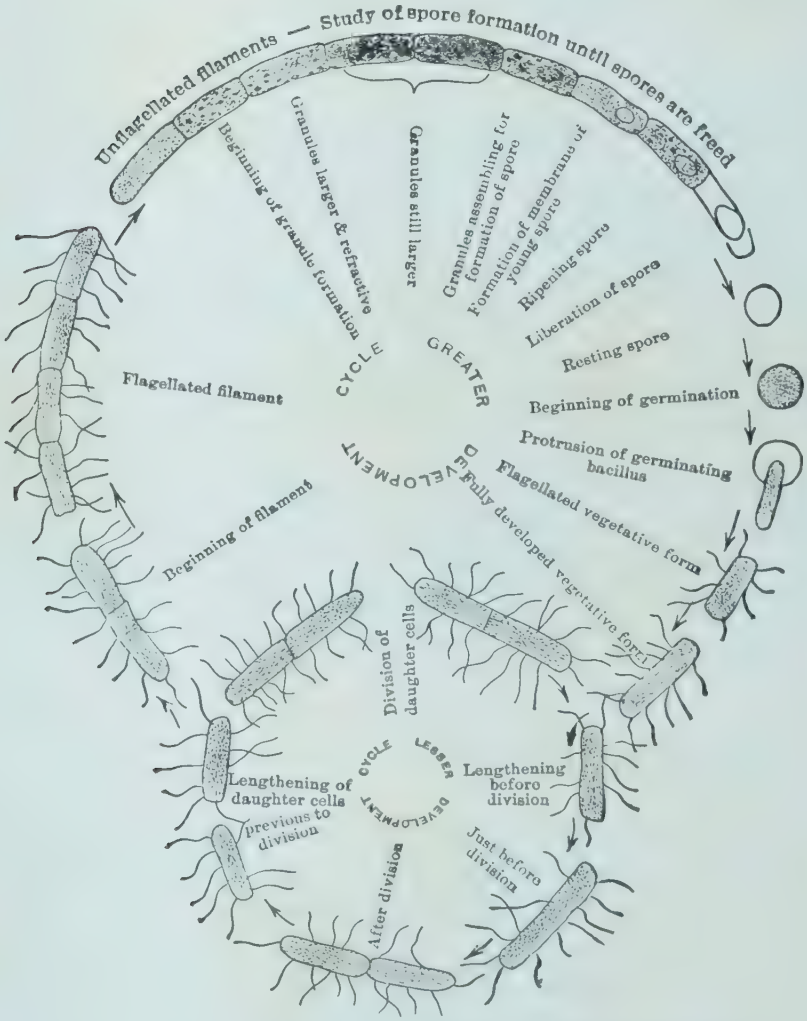
In measuring milk quality it is not enough to be able to simply note appearance and odor. The bacterial count is the most frequently used test for the quality of milk and its products. A number of chemical and physical quality tests have been developed for use on products as received and in manufacturing operations.

THE BACTERIOLOGY OF MILK

Definition of Bacteria. Bacteria are microscopical organisms belonging to the plant kingdom. They are unicellular and have no method of multiplication except by fission or cell division. Under optimum conditions bacteria may divide once each half-hour; this means that in 24 hours one organism might have 17,000,000 descendants. They vary in size but are so small that millions may be present in one milliliter of milk. Bacteria, or microorganisms as they are commonly called, are found throughout nature except at

considerable depths in the earth, extremely high altitudes, and in healthy normal tissues of plants and animals. An understanding of the common types of bacteria—how they grow, where they come from and what they do—is very essential in handling milk and its products.

Factors Affecting Growth. FOOD. All living cells require some source of energy for growth. The common chemical and mineral food elements are just as essential to bacteria as they are to the members of the animal kingdom. Milk, one of the most desirable



(Adapted from Fuhrmann's Technische Mykologie.)

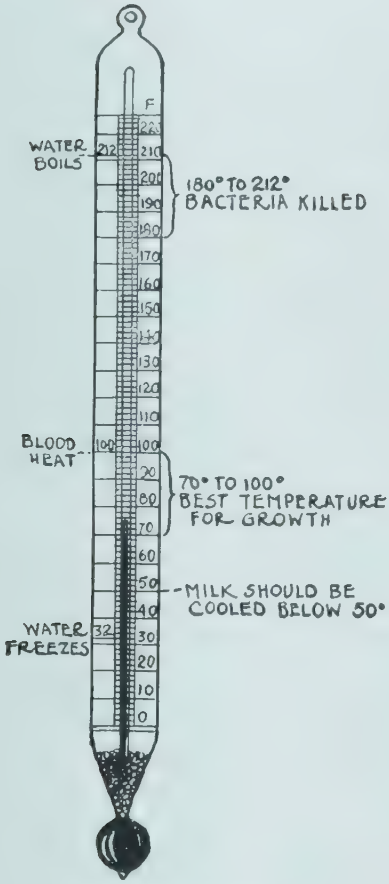
Fig. 66. Cycle of development of bacterial cell.

and perfect foods for human beings and animals, is likewise an excellent food for bacteria.

REACTION. By reaction the bacteriologist means the degree of acidity or alkalinity of the medium containing bacteria. The growth and even the viability of bacteria are governed to a considerable extent by reaction of the surrounding medium. All species of bacteria exhibit a so-called reaction range within which they thrive, grow, and multiply. At a point somewhere within this range, designated as an optimum, they exhibit their greatest activity. The most favorable reaction for the majority of bacteria is at or near the neutral point, but a few species, such as the tubercle bacillus, can tolerate, or the lactobacilli prefer, relatively large quantities of acid. Should we test the reaction of milk when lactobacilli are in abundance, we would find it to be definitely acid.

TEMPERATURE. Bacteria do not grow or multiply to any great extent at freezing temperatures, but between 70° and 100° F we get extremely rapid growth and multiplication. Different organisms vary somewhat with regard to their optimum temperatures but nearly all of the bacteria that are commonly found in milk thrive under temperatures from 70° to 100° F. These same bacteria multiply very slowly at temperatures below 50° F. This fact shows why milk and its products must be cooled rapidly after milking or processing and be kept refrigerated until used. At temperatures slightly above 100° F they begin to be killed. The process known as pasteurization, which consists of heating to a temperature of 142° to 145° F for 30 minutes, kills most of them. Investigations by Robertson, Breed, and others have shown that there are certain types of bacteria that habitually survive pasteurization and others that increase at pasteurization temperatures. The former are known as thermoduric or heat-enduring organisms, and the latter as thermophilic or heat-loving. Both of these types are nonpathogenic and harmless but they constitute a real problem in the checking of pasteurization efficiency. Their control is extremely difficult under commercial conditions and special bacteriological methods are necessary to determine their presence and estimate their numbers. Pasteurization should not be confused with sterilization. When a thing is sterile, no living organisms are left on it or in it. To sterilize milk, it must be heated in small quantities under steam pressure to about 240° F for 10 or 15 minutes, or boiled for 20 minutes on three successive days.

MOISTURE. Since bacteria get their food from aqueous solutions, water is absolutely essential for growth and development. Dried foods, such as dried milk and dried fruit, may contain some bacteria.



(*From Kentucky Bul. 206.*)

Fig. 67. Graphic representation of the relation of temperature to bacterial control.

That is, although drying may kill some organisms it does not kill all of them. Those remaining are able to exist on the dried article without eating, so to speak, but they are not able to multiply. When moisture is added to the dried article, bacterial multiplication again ensues. Moisture and temperature are the all-important factors affecting bacterial growth.

AIR. Most bacteria grow only in the presence of air or free oxygen. This class is known as aerobic, whereas those that grow without free oxygen are known as anaerobic. The types that can adapt themselves to either condition are called facultative.

Morphology or Shape of Bacteria. There are four principal types of bacteria cells: (1) the spherical organism known as a coccus; (2) the rod-shaped one designated as a bacillus; (3) the spirillum or spiral organism; (4) the filamentous type, which develops long filaments and is termed trichobacteria. The ones most commonly found in milk are the coccus and bacillus.

Common Types of Bacteria Found in Milk. ACID-FORMING ORGANISMS. This type of organism is almost always present in milk. There are many different strains of acid-forming bacteria that cause milk to sour. The most common group is referred to as Streptococcus lactis. These organisms are responsible for the normal souring of milk which is brought about by the action of bacteria on lactose or milk sugar. The lactose is broken down into lactic acid, which causes a thickening or curdling and a sour flavor. Although all bacteria are a nuisance in the market-milk business, these acid-forming organisms are indispensable in cheesemaking. They are also important in the manufacture of sour or ripened cream butter and in certain sour milk drinks.

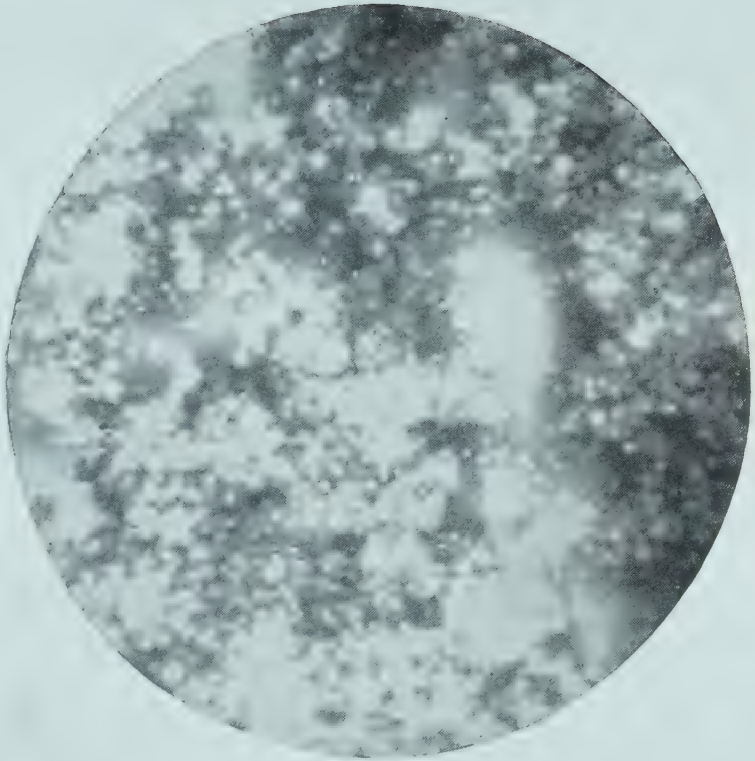
Other strains of acid-forming organisms are: Lactobacillus acidophilus, Lactobacillus casei, and Lactobacillus bulgaricus.

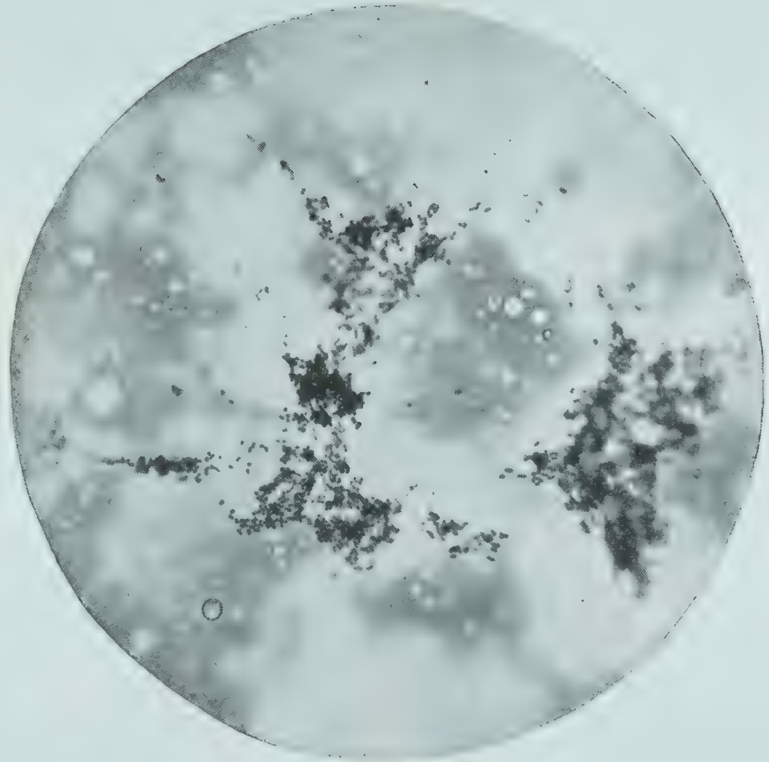
The principal source of the acid-forming bacteria in milk is the utensils—this is especially true of Streptococcus lactis. Bacteria of this group should not be confused with the long, chain streptococci which produce inflammation and are considered harmful to health.

GAS-FORMERS. These bacteria not only cause milk to sour, but also cause gas to develop. They are classified as the Escherichia-Aerobacter or colon-aerogenes group, the principal type species being Echerichia coli and Aerobacter aerogenes. Both of these types are non-spore-forming rods. They ferment glucose and lactose, forming both acid and gas. The Escherichia type comes primarily from the intestinal tract of man and animals. This fact established the importance of keeping barn filth and cow manure out of the milk. The aerobacter type is found sometimes in the intestines of man, and in the soil and grains, which in turn brings out the importance of clean, dry pastures and barnyards, good grain and hay.

These organisms are always undesirable in dairy products. They cause highly undesirable flavors and odors and, in addition, often prove harmful to humans, especially infants, in that they are likely to cause digestive disorders. Milk containing these bacteria is almost worthless for cheesemaking because of the bad flavor and gassy body developed in the cheese.

LIQUEFIERS. The bacteria which cause the liquefying or proteolysis of milk are almost always associated with or identical to those which cause sweet curdling. The curdling of milk or cream by microorganisms without the formation of enough acid to cause coagulation is defined as sweet curdling. Liquefying or proteolysis is described as the process by which casein is broken down to a water-soluble compound. The degree of decomposition from these two processes





(*From New York (Geneva) Exp. Sta. Circular 93.*)

Fig. 68. When a drop of clean high-grade milk is dried on a glass slide and then colored by immersion in a blue stain, it has the appearance shown above, when seen under the microscope. No bacteria can be found. The background shows white circles where the fat drops have been dissolved out of the dried milk solids. A few white blood corpuscles may occur in milk of this type, though none is to be seen in the picture. Magnified 600 times.

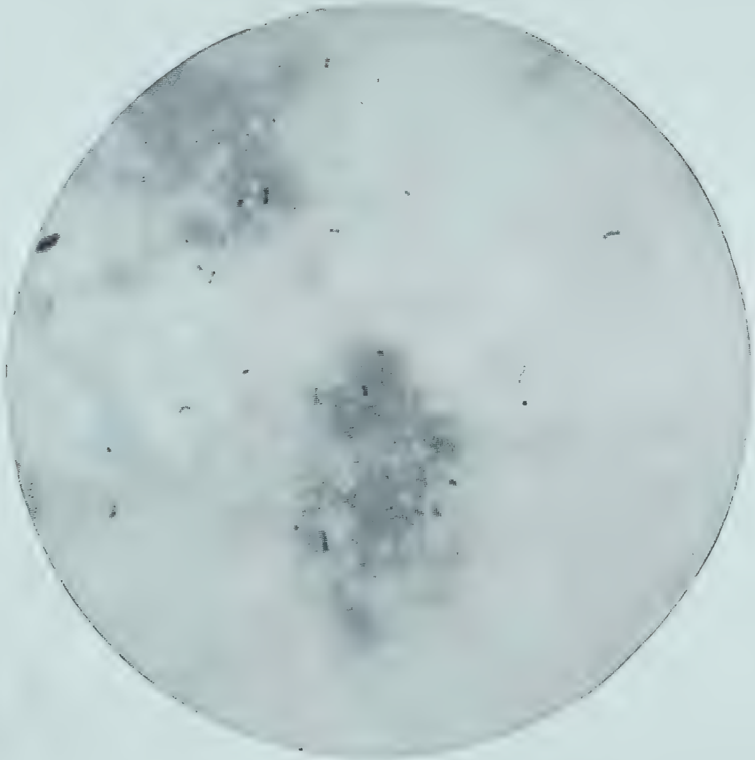
Fig. 69. When high-grade milk is placed in improperly cleaned utensils, it takes up masses of bacteria such as are shown in the above picture. When the milk is stained for microscopic examination these become evident as deep blue specks of various shapes. Bacteria in utensils produce putrid, unpleasant odors as they cause the decay of the remnants of milk left in rinse water or in open seams. Magnified 600 times.

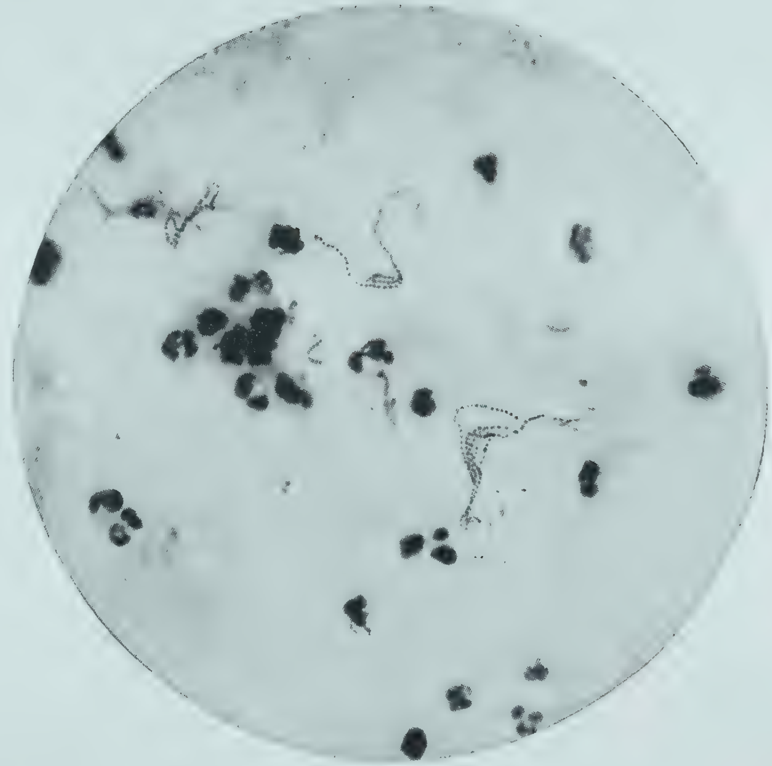
depends largely upon the types of organisms and the temperatures. Streptococcus liquefaciens is one of the most important organisms in this group, which as a whole is associated with unsanitary conditions of production.

PSYCHROPHILES. These bacteria grow at temperatures below 50° F and can be very bothersome. They affect the keeping quality of milk and cause the development of such off-flavors as fruity, rancid, bitter, stale, musty, and sometimes putrid. Fortunately, they are destroyed by pasteurization, but trouble from these organisms is caused after pasteurization by contamination from equipment. Common sources of the organisms are soil and water—hence the importance of very thorough sterilization of all product contact surfaces following pasteurization.

DISEASE ORGANISMS. Although not commonly found in milk, disease organisms may cause very serious results when they are present. Too much care cannot be exercised in preventing milk from becoming contaminated with bacteria that cause disease. Diseases that have been spread by milk include tuberculosis, typhoid fever, scarlet fever, poliomyolitis, undulant fever, septic sore throat, diphtheria, and intestinal troubles of infants and invalids. It will be seen that, of these diseases, the only ones which might be traced to the cow are tuberculosis and undulant fever. The eradication of tubercular cattle from our dairy herds has considerably lessened the chances of tubercular infection of bovine origin. Undulant fever in man may be caused by the use of raw milk drawn from an infected udder. The causative organism belongs to the genus Brucella. Although Brucellosis of cattle is widespread and results in an enormous annual economic loss to the dairyman, the number of cases of human infection is relatively small. Nevertheless the danger exists, and the desirability of establishing Brucella-free herds, especially if the milk from them is to be consumed raw, is now a recognized responsibility of both the dairymen and health officials. Improved bovine and human health measures, coupled with pasteurization, have made milk-borne epidemics almost a thing of the past.

Yeasts and Molds. Yeasts and molds are closely related to bacteria, and cause important changes in milk and its products. Yeast cells are generally larger than bacteria, and they multiply by budding. A bud appears on the side of the yeast cell, and after a time it grows as large as the mother cell and breaks off. Yeast may cause a yeasty flavor in cream, together with a foamy development. Yeasts seldom act on milk sugar, but are very active on cane sugar, produc-





(From New York (Genevā) Exp. Sta. Circular 93.)

Fig. 70. When high-grade milk is allowed to stand without adequate cooling, the bacteria that cause the normal souring of milk grow rapidly. These show in the above picture as pairs or double pairs of minute specks. Bacteria of this type produce a sour but not putrid odor. Magnified 600 times.

Fig. 71. When milk is drawn from a cow suffering from mastitis (garget), the milk contains enormous numbers of white blood corpuscles and beadlike chains of the bacteria that cause the inflammation. These are so characteristic that they are readily found in milk even when it is diluted with large quantities of good quality milk. Magnified 600 times.

ing alcohol and carbon dioxide. For this reason, yeasts are sometimes troublesome in sweetened condensed milk.

In addition to the true yeasts, there is a group of organisms known as *torulae* or false yeasts. To two types (Torula cremoris and Torula sphaerica) in this group, is charged the bulk of gassy and foaming cream.

Mold are plants large enough to be seen with the naked eye. There are many varieties of molds. They are especially bothersome in the manufacture and storage of butter and cheese. The mold may not only grow upon the surface of butter or cheese, but may develop on the inside of the package as well. Clean storage conditions and proper temperature and humidity do much to check mold development. Some cheeses, such as Camembert, require the presence of certain molds to develop the proper flavor during the ripening process.

Number of Bacteria in Milk. The number of bacteria, usually known as the bacterial count, is given as so many per cubic centimeter (milliliter). In 1953 the U.S. Public Health Service suggested the maximum number of bacteria which should be allowed for various grades of milk by the plate count.

Raw Milk:
Certified: must conform to requirements of the American Medical Milk Commission. Common standard is 10,000 per ml or less.
Grade A–For pasteurization 200,000 bacteria per ml or less.
B–For pasteurization 1,000,000 bacteria per ml or less.
C–For pasteurization milk not meeting Grade B requirements.

Pasteurized Milk:
Grade A–30,000 bacteria per ml or less.
B–50,000 bacteria per ml or less.
C–Not meeting Grade B requirements.

Careful local supervision has resulted in more stringent standards in many communities. It is now difficult to imagine that in 1900 it was found extremely difficult in New York City to enforce a regulation limiting bacteria to 1,000,000 per ml. Milk is rated as stated above and milk with a high bacterial count is considered undesirable because high counts may indicate: (1) old milk, (2) improper refrigeration, or (3) the use of unclean methods in production and handling. Milk with a high count is more likely to be harmful to the public health than low-count milk, because we now know that normal, fresh, properly refrigerated milk produced and handled by intelligent

individuals with the aid of modern sanitary devices continually gives a low count when examined by the bacteriologists.

Methods of Counting or Estimating Bacteria. THE PLATE METHOD. This method employs the principle of mixing a given weight or volume of material (milk) with a fluid culture medium (standard tryptone–glucose–extract milk agar) which solidifies, and then counting the colonies developing on incubation. The numerical results are at best only estimates of the bacteria in the milk. No single culture medium or any single set of standard conditions will give evidence of the bacterial population in a specific quantity of milk. Many times the word "count" is used to express results of quantitative plating; if so, the word must indicate an estimate and not an exact numerical quantity. Directions for the making of standard agar, the necessary equipment, technique, and so on, should be carefully studied.* A properly obtained milliliter sample of milk is diluted in sterile water so that the number of colonies appearing on at least one of the plates will be between 30 and 300. If the analysis is to determine whether the count exceeds the limits of 10,000 to 30,000 per ml, prepare at least two plates per sample. Use at least two dilutions, preferably 1:100 and 1:1,000; a third dilution of 1:10,000 may be prepared if the anticipated count is expected to be in excess of 300,000 per ml. If a low bacterial count is anticipated, prepare plates from 1:10 and 1:100 dilutions. *Standard Methods for the Examination of Dairy Products* should be consulted for the procedure required for mixing the original sample and shaking the various dilutions. The recommendations must be followed closely. Most bacteria as they exist in milk are in clumps or chains; improper shaking or mixing can greatly affect the final results. Using a 1-ml pipette, put 1 ml of the dilution into a sterile glass plate known as a petri dish. Use care to raise the cover of the petri dish only as far as necessary to insert the end of the pipette. Next pour about 10 ml of the melted agar (40° to 45° C) into the diluted milk in each inoculated petri dish and thoroughly mix them with a gentle rotary motion. As soon as the agar has hardened place the petri dishes in an incubator at 37° C (98.6° F) for 48 hours. After the incubation period is completed count the colonies. If among the different dilutions there are plates containing from 30 to 300 colonies, these should be counted and the number, multiplied by the dilution, should be reported as the final count. When plates contain less than 30 or more than 300 colonies and must be used for estimating the count, a statement of

* *Standard Methods for the Examination of Dairy Products*, 10th edition, 1953.

this fact should be made a part of the written report. Counting should be done with a lens, and all recognizable colonies included. The standard plate count gives a fairly accurate count of the living bacteria in milk and is especially applicable in determining the bacterial count of low-count products, such as high-grade cow's milk and pasteurized milk.

MICROSCOPIC OR BREED METHOD. This method is a direct microscopic examination of a dried film of milk. A single reagent, containing solvent, fixing agent and methylene-blue stain, known as the Newman-Lampert Formula No. 2, may be substituted for xylol, alcohol, and methylene-blue solution of the original Breed stain. This so-called Newman method of staining is used extensively by technicians in field work because of its simplicity and convenience. Preparations with it may lack clearness and thus are less satisfactory then those prepared by the use of the three separate reagents. The Breed microscopic method can be used for grading market milk and for the detection of high counts produced by specific groups of bacteria, as well as routine counting. In quality-control work, this test is becoming more and more valuable and in many instances can

Fig. 72. Placing the prepared plates in the incubator.

Fig. 73. Counting bacterial colonies on a plate. (Courtesy Agricultural and Technical Institute, Delhi, N.Y.)

be substituted for the more costly and time-consuming plating technique. After a thorough shaking of the sample, 0.01 ml of milk, measured with a capillary pipette, is spread uniformly over an area of 1 square centimeter on a glass slide. It then is dried and dipped in xylol, or any other suitable fat solvent, for a sufficient time to remove the fat. After this it is drained, dried, and then washed in a 90 per cent grain or denatured alcohol solution. The film finally is stained with a solution of Loeffler's methylene-blue, decolorized in alcohol and examined with a microscope adjusted so that each field covers a certain known fraction of a square centimeter. Knowing this fraction, the number per cubic centimeter can be calculated easily. In comparing the counts made by the plate method and the microscopic or Breed method, the general assumption is made that the plate count will normally average one-fourth of the total number of individual bacteria present, except with the poorest grades of milk. The Breed method is especially valuable to the experienced

technician, as the causes of high counts are revealed by the type of microorganisms present. An example is the long-chain streptococci associated with mastitis.

SPECIAL TEST FOR SPECIFIC GROUPS AND SPECIES. Tests for coliform organisms may serve the following purposes: (1) to check on general sanitary conditions during production, (2) to determine the presence of udder inflammation caused by certain species of the coliform group, and (3) to evaluate the efficiency of pasteurization. Normally, coliform bacteria are destroyed by pasteurization; their presence in pasteurized milk indicates faulty processing.

Examination of milk samples for hemolytic streptococci, tubercle bacilli, and organisms of the Brucella group assists in tracing the epidemiology of disease produced by these germs and also aids in the routine examination of producing animals for the detection of diseased conditions. In many instances, seriological methods can be substituted for or used to supplement the bacteriological procedures. Again we must emphasize that these special tests require time, highly trained technical workers, and, in many instances, expensive equipment. Until such time that many of these difficulties are lessened or eliminated and the laboratory technician can employ quick, efficient, direct methods for detecting milk pathogens, we must depend upon the pasteurization of clean milk to insure a safe product.

SOURCES OF BACTERIA IN MILK. The sources of the common milk bacteria are the cow's udder, the body of the cow, the air, the utensils, the milker, and flies.

At one experiment station, 1,230 samples of freshly drawn milk from healthy udders showed the average count due to udder contamination to be 428 per milliliter, proving that milk fresh from the udder usually shows a very low count. The bacteria work their way up through the opening in the teat from the outside, and multiply principally on the milk in the streak canal and the teat cistern. These bacteria are of varied types: some will cause milk to sour; others will liquefy the casein in the milk; others will cause intestinal trouble; and if an udder is affected with tuberculosis, children may contract the disease from using the milk. Whenever a cow's udder is diseased or inflamed, the count is naturally high. Some cows have chronic udder trouble and always give milk high in bacterial count. A cow of this type has no place in a dairy trying to make high-grade milk.

The cow's body is the source of most of the dirt that gets into the milk and of some of the most destructive bacteria, such as the gas-formers. The bacteria from the body of the cow come primarily

from the manure and dirt lodged on the animal, and this, in turn, comes indirectly from feed and bedding.

Not as many bacteria get into the milk from the air as was formerly supposed, although, when dusty feeds are given at milking time, there may be a considerable number. Bacteria from the air come mainly from feed and bedding. Nearly all types are represented, the acid-formers and liquefiers being most common.

The greatest number of bacteria that get into milk come from improperly washed and unsterilized utensils. Fortunately, most of the bacteria from this source are acid-formers and they can be killed easily by proper sterilization.

The milker, or the person who handles the milk after it is drawn, must be careful. If he is sick, or feels sick, he is in no condition to handle milk. He may become the source of the bacteria that cause one of the serious milk-borne epidemics of the diseases previously mentioned.

The fly is always dangerous because of its habits of living and the consequent danger of its seeding milk with disease germs.

Types of Abnormal Milk. SALTY MILK. Salty milk has a foul smell and a salty taste. It does not occur very often. The cause is not known, but it seems to occur more often with cows advanced in lactation, or with cows that have been milked for a long time without much rest for calving.

BITTER MILK. This is a common type of abnormal milk. It may be due to some feed that the cow has eaten; if so, the milk will taste bitter as soon as it is drawn. Certain bacteria, the source of which is unknown, also may cause bitter milk to develop on standing. The remedy, in this latter case, is to take greater care as to cleanliness of production and pasteurization until the trouble disappears. Bitter milk also may be due to the enzyme lipase which splits fat into glycerol and fatty acids. The fatty acids cause the milk to be bitter. This condition occurs generally in late lactation and the only solutions are to turn the cow dry or heat the milk shortly after milking to inactivate the enzyme.

BLUE MILK. Blue milk is very uncommon. It is caused by a bacterium, Bacillus cyanogenes. The milk is not blue when drawn but develops the blue color on standing. The immediate remedy is pasteurization of the fresh milk, which should be followed by a careful cleaning up of milk-handling equipment. Little is known as to the source of the organism.

YELLOW MILK. The same thing can be said for yellow as for blue

milk, except, of course, that it is caused by a different species of bacterium.

BLOODY OR RED MILK. This defect is usually caused by blood, which gets into the milk from a ruptured blood vessel in the udder. Blood is heavier than milk, and it usually will be noted near the bottom of the milk bottle, or clinging to the bowl of a separator, in the slime. If the cow can be kept quiet, the trouble may be healed during the milking period; but it usually is necessary to dry off the cow to allow time for a bad case to heal. Red milk sometimes is caused by bacteria, the source of which little is known. There are a number of kinds of bacteria that will cause a red color in milk, but they seldom cause trouble.

ROPY MILK. Milk drawn from cows affected with a bacterial udder trouble, known as garget, is sometimes called ropy. In reality, it is merely very slimy. It is almost impossible to strain slimy milk through cheesecloth. The conditions that bring on this trouble are not thoroughly understood. A cow may contract it from an udder bruise, by lying on a cold floor, or from faulty feeding. Some cows have the trouble frequently, and it is best to get rid of them.

Real ropy milk is caused by bacteria, and is developed after the milk is drawn from the cow. Such milk, when put through a wire strainer, will form strings several feet long. This milk is not harmful to health, but is very bothersome, since it is not salable in this condition, nor can it be used for anything except, possibly, swine feeding. The source of the organism is thought to be surface water and, possibly, at times, a diseased udder. Careful sterilization of utensils usually will eliminate this trouble. Pasteurization of the milk in the plant offers a temporary remedy, if all equipment with which the milk comes in contact following pasteurization is properly sterilized.

MILK FROM COWS LONG IN MILK. Such milk may have almost any of the troubles mentioned. Abnormal milk is most common in the case of cows near the end of their lactation period.

MILK FROM SICK COWS. This is likely to be abnormal in character and dangerous to health. No chances should ever be taken in using or selling milk from sick cows.

Bacteriophage. Bacteriophages are viruses that attack and destroy bacterial cells. They are much smaller than the bacteria they destroy. In the process the bacteriophage, or phage as it frequently is termed, attaches itself to the cell, enters the protoplasm, and then reproduces at the expense of the organism. The result is a completely disintegrated and destroyed cell and a large number of new

phages. Any one phage is capable of attacking only a certain specific strain or strains of bacteria. The phages important to the dairy industry are those that attack lactic acid and aroma bacteria and thereby cause "slow" or "dead" starters. Studies indicate that most major cases of starter failure in recent years have been due to bacteriophage, although some have been traced to antibiotics and other causes.

Higher than normal pasteurization temperatures, careful sterilization of equipment, and even spraying of hypochlorite solution into the air of processing rooms have proved helpful in controlling bacteriophage.

Antibiotics. Various antibiotics are used by producers for injecting into the cow's udder for controlling mastitis or "garget." Milk from such cows may be sold without sufficient time interval elapsing and thus cause trouble for the plant.

Antibiotics in milk used for cultures, bulk starters, and cultured products such as buttermilk and cottage cheese may result in failure of bacteria to produce the desired lactic acid and other flavors and aromas desired. Because of the nature and low concentration of these compounds, their presence in milk is difficult to detect before the milk is used.

CHEMICAL AND PHYSICAL TESTS

The Acidity Test. The acidity test is one of the most commonly used determinations in dairy control work. The test is used for grading both cream and milk for quality and also is used as a guide in controlling dairy processes, such as cheese making and cream ripening. The test is very valuable to the buyer of milk and cream in telling whether the producer has cooled his product and kept it cold until delivery. In general, acidity is measured in two entirely different ways; first, as hydrogen-ion concentration or pH and, second, as titratable acidity. Both ways of measuring acidity are based on the fact that all acids contain "acid hydrogen." Therefore, the combining power of all acids is due to the amount of acid hydrogen which can be replaced in chemical reactions. The concentration of the replaceable hydrogen (or hydrogen ions) is commonly expressed as pH; water, which is neutral in reaction, has a pH value of 7. The pH of fresh milk, which is slightly acidic in reaction, is approximately pH 6.5 to 6.7. Because the methods for measuring pH are too technical for practical dairy work, they seldom are used except in re-

search and are not given here. The titratable acidity of fresh milk is, by the test to be described, about 0.17 per cent; however, the acidity may vary considerably from one fresh milk to another.

Causes of Acidity in Milk. Fresh milk actually contains no acid; yet it has a definite titratable acidity. This fact indicates that the chemical used in the acidity test combines with some of the substances in normal milk. Hence, the milk appears to contain acid when it is absolutely fresh. This reading, often referred to as "apparent acidity," should not be confused with the actual acidity which may be formed later in the milk by bacteria. The substances which give milk its apparent acidity are: (1) the phosphates and citrates (minerals), (2) the casein and albumin (proteins), (3) dissolved carbon dioxide. High-testing milk averages a slightly higher content of proteins and minerals than low-testing milk; for this reason the acidity reading of fresh milk varies from about 0.13 per cent for low-testing milk to 0.2 per cent for high-testing milk. It is evident, therefore, that a high natural acidity in milk is not objectionable. This natural acidity does not increase in milk and does not make milk taste sour. After milk has been drawn from the cow, certain types of bacteria known as "acid-formers" find their way into it. Under favorable conditions these bacteria act on milk sugar and change some of it to an acid called lactic acid. This is the acid which makes milk taste sour. Conditions favoring the development of acidity are lack of cleanliness in handling milk, especially the use of unclean utensils, and improper cooling of the milk. When milk is cooled to 50° F or below, and kept at this temperature, the bacteria will multiply very slowly and the milk will stay sweet for a long time. In hot, sultry weather it is more difficult to keep milk and cream sweet because proper cooling is difficult. Some people believe that thunderstorms sour milk. This belief is attributable to the fact that the weather prior to a thunderstorm is usually hot, sultry, and quite favorable to bacterial growth. Other than this, there is nothing about a thunderstorm which can sour milk. Only the action of bacteria on the milk sugar can cause milk to sour.

$$\underset{\text{(Lactose or milk sugar)}}{C_{12}H_{22}O_{11}} + H_2O + \text{Bacteria} = 4\ \underset{\text{(Lactic acid)}}{C_3H_6O_3}$$

Milk usually develops 0.05 per cent to 0.1 per cent acid before it begins to taste sour, so that milk containing an acid equivalent of 0.14 per cent when drawn from the cow might taste sour at 0.21 per cent acid, whereas other milk with an equivalent of 0.2 per cent

acid when drawn would have 0.25 to 0.3 per cent acid before it developed a sour taste. Under suitable conditions acid develops rapidly in milk until 0.6 to 0.7 per cent is formed. At this point the acid acts as a preservative, retarding bacterial growth, so that an additional amount of acid forms slowly, and the total seldom reaches more than 0.8 to 1 per cent.

Reasons for Necessity of an Accurate Test for Acidity. Milk, and particularly cream, delivered at creameries and milk plants may be bought in two or more grades, the farmer receiving more for Grade I than for Grade II. One of the factors that determines the grade of cream is the acidity. For example, the creamery standard for Grade I cream is likely to be not over 0.25 per cent acid. Because sourness in cream cannot always be detected by taste at this point, some accurate test is necessary.

Milk and cream with an acidity of less than 0.18 per cent is given a perfect score of 15 points on acidity, on the score card used in scoring milk and cream for shows. If the acidity is over 0.23 per cent the score is 0. Here is seen the necessity of a test that will ascertain the acidity of milk within 0.01 per cent.

Some accurate method must be used in selecting cream for ice-cream making and for the sweet-cream trade, if it is desired that the cream be not merely sweet but far from the souring point.

In making butter, cream is commonly ripened or soured until it has about 0.4 per cent acid. The acid test shows when this point is reached. Cheesemaking is decidedly a step process; that is, one operation must be completed to a certain point before the next step is taken. The acid test indicates when the different steps should be taken. The acidity test is also a valuable tool in making cultured buttermilk.

Principle of the Acid Test. There are three substances the nature of which must be clear if one is to understand the acid test. They are acid, alkali, and indicator. Examples of acids are sulphuric acid (used in the Babcock test) and the lactic acid in milk. Washing powder and ammonia are alkalies. Acids and alkalies are opposite in their properties, hence, when mixed in right proportions, the resulting mixture has neither alkaline nor acidic properties, but is said to be neutral. In the acid test the alkali, sodium hydroxide ($NaOH$), usually is used to neutralize the acid in the milk. It is obviously necessary that an indicator must be used to show when enough alkali has been added to neutralize the acid in the milk. This indicator is phenolphthalein. The indicator remains colorless when in an acid

substance, but is pink in an alkaline medium. Therefore, the acid test is based on the principle that when an alkali is added to milk in the right proportion, the milk is made neutral, and a very slight excess of alkali causes the mixture to develop a slight pink color. This color shows that the right amount of alkali has been added. There are a number of acid tests based on this principle, the Manns' test being most commonly used.

Manns' Acid Test. This test, which was developed in 1890 by Dr. A. G. Manns of the Illinois Experiment Station, is widely used in dairy work. The pieces of equipment needed for the test are a graduated burette, a 17.6-ml pipette, a glass stirring rod, a cup or beaker, some indicator and 0.1 *N* sodium hydroxide. Though the chemicals can be purchased ready for use from dairy supply houses, persons with some training in chemistry easily can prepare the solutions. To operate the test, pipette 17.5 ml of milk into the cup. Where cream or other viscous dairy products, such as ice-cream mix or condensed milk, are being tested they should be rinsed from the pipette into the cup with an equal quantity of warm, soft water. For more accurate results, weigh 18 g into the cup. Add 3 to 5 drops of indicator to the sample and stir. Fill the burette with NaOH and take the burette reading. Slowly, with constant stirring, run the alkali into the sample in the cup until a faint pink color appears. Again read the burette to see how much alkali has been used. To calculate the percentage of acid in a sample, divide the number of milliliters of alkali used by 2, and write the answer in tenths of 1 per cent. For example, if the first burette reading was 8 ml and the second one 12 ml (the burette reads down), 4 ml was required. $4 \div 2 = 2$, which means that the sample had a 0.2 per cent of acid in it. This rule can be used only when 17.5 or 18 g are used as the sample. Otherwise the following formula is used:

$$\text{Per cent acidity calculated as lactic acid} = \frac{\text{ml NaOH used} \times 0.009 \times 100}{\text{grams in sample}}$$

Working the above problem with this formula will show how the short rule is devised when an 18-g sample is used:

$$\text{Per cent acidity calculated as lactic acid} = \frac{\overset{0.002}{\cancel{4} \times \cancel{0.009}}}{\underset{2000}{\cancel{18}}} \times 100$$

$$= 0.2 \text{ per cent}$$

This formula is used because 1 ml of 0.1 *N* NaOH will neutralize 0.009 g of lactic acid. Viscous dairy products, such as cream, ice-cream mix, and evaporated milk, are usually diluted with an equal quantity of water. This lowers the viscosity sufficiently and facilitates the performance of the test. It is essential always to use the same amount of water in the test to get uniform results. The addition of water to the acidity test has been found to lower slightly the acidity reading. Hence the use of a larger quantity of water would affect the accuracy of the results.

Grading Milk and Cream with Rapid Acid Test. Whenever it is desirable to know whether a number of samples are above or below a certain percentage of acidity, as in the grading of cream delivered to a creamery, the Manns' test can be modified for this use, as follows: take 100 ml of 0.1 *N* NaOH and add a sufficient amount of soft water to make a total volume equal to 90 divided by the percentage of acidity taken as the acidity standard in grading. For example, if cream testing 0.2 per cent acidity or less is required in Grade I, then $90 \div 0.002 = 450$. The 100 ml of alkali must be diluted with soft water to a volume of 450 ml. Add enough indicator to the dilute alkaline solution to produce a wine red color. When equal quantities of cream and the rapid test solution are mixed, a pink color indicates 0.2 per cent acidity or less. If the mixture is white, then there is more than 0.2 per cent acidity and the cream cannot be classed as Grade I. In actual practice, half-ounce dippers are used for measuring equal quantities of cream and the test solution. By using one dipper of cream to two of the test solution, the turning point is at 0.4 per cent acidity.

The Sediment Test. The presence of visible dirt in milk is undesirable; it indicates that the milk was produced in a careless manner. Furthermore, it seems logical to assume that milk carelessly produced also might be unnecessarily contaminated with bacteria. The two do not necessarily go hand in hand, but a producer who allows visible dirt to get into milk also may be careless in other respects which affect the quality of milk.

The purpose of the sediment test is to measure the insoluble or visible dirt in milk. This is accomplished by filtering a pint of milk through a firm cotton disk placed over an opening 1 in. in diameter. Thus the sediment from the pint of milk is collected on the cotton disk, where it is seen easily. Several types of sediment testers are available; this makes the test simple to run. The amount of sedi-

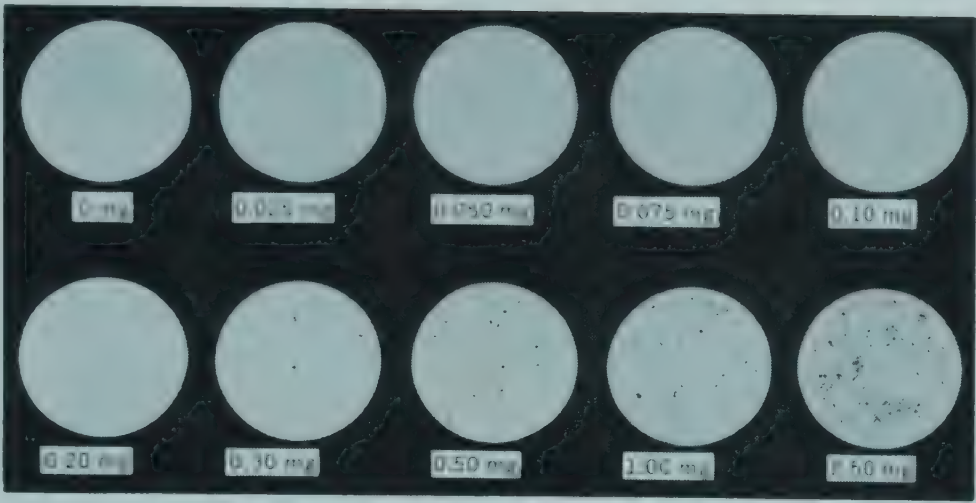


Fig. 74. U.S. Department of Agriculture sediment standards for milk and milk products.

ment in the milk can be given a numerical rating by comparing the disks with a photographic standard, such as Fig. 74. The returning of sediment test disks to milk producers whose milk was not so clean as it should have been has been effective in improving milk supplies.

The Methylene-Blue Reduction Method. This test, often called the reductase test, is based on the fact that the color imparted to milk by a small amount of methylene-blue will disappear more or less quickly, depending almost entirely on the number of bacteria in the milk. The value of the method is that a large number of milk samples can be tested for quality in a comparatively short time, and with very little equipment. Because this is true, the reductase test is used by milk companies and control officials in upgrading a relatively poor milk supply. The method consists in placing 1 ml of a methylene-blue solution of standard strength into a test tube. To this is added 10 ml of the milk to be tested. The tube then is stoppered and placed in an incubator at 37° C. The length of time required for the blue color to disappear is observed. The blue color will persist for a relatively long period of time in milk of low bacterial content. The following classification is suggested by the American Public Health Association for the results of the reductase test:

Class 1–Excellent, not decolorized in 8 hours.

Class 2–Good, decolorized in less than 8 hours, but not less than 6 hours.

Class 3–Fair, decolorized in less than 6 hours, but not less than 2 hours.

Class 4–Poor, decolorized in less than 2 hours.

The Resazurin Test. The resazurin test has been used in America since 1935. It is performed in the same manner as the methylene-blue reduction method except a solution of the dye, resazurin, is used instead of methylene-blue. The advantage of the method is that a short incubation period (1 hour) is used.

The Fermentation Test. This test consists of holding milk in test tubes at 37° C until it coagulates. Then the type of curd which forms is studied. The fermentation test is usually run in conjunction with the methylene-blue reduction method, merely by holding the tubes after they have been decolorized. By observing the milk samples after coagulation, the type of fermentation can be determined. This furnishes an insight into the types of bacteria present. A smooth, uniform curd means that ordinary lactic-acid-producing bacteria are present. These organisms come largely from pails, strainers, and so on, which are not properly sterilized. Sometimes a curd which is spongy and full of gas holes is formed; or the curd may be partially liquified, forming whey. Gas-forming bacteria and liquifiers come from dirt, dust, hay, and manure. Contamination of this type can be prevented by milking in clean surroundings and washing the cows' udders before milking. Because the fermentation test indicates the types of bacteria in the milk and the reductase test indicates the number, the results of the two tests mean more when used together.

Laboratory Pasteurization Test. The laboratory pasteurization of a small amount of each patron's milk is now a common test, especially in the larger dairy companies. The purpose of the test is to determine to what extent the bacteria present in the milk from each farm will be destroyed by pasteurization. The thermoduric organisms that are not destroyed indicate unsanitary conditions, notably unclean utensils, and it is these farms that need the first attention of the field man. The method is simple. A 10-ml sample of each milk to be tested is placed in a test tube, using sterile equipment. The test tubes are placed in a hot-water bath; the temperature of the bath is brought to the pasteurization temperature and held for the required time, when the samples are cooled. The bacterial content of each

Fig. 75. A well-equipped laboratory for quality control of dairy products.

milk is then determined by the official agar-plate method, or the oval test tube method may be used whereby a known fraction of a milliliter of milk is transferred to a tube of melted agar with a wire loop. The tubes are incubated and the bacterial colonies on the surface of the agar are counted. Another method is to pasteurize a fraction of a ml of milk in a test tube of agar, cool and incubate the tubes, and count the colonies. This procedure saves considerable time. By means of the laboratory pasteurization test it is possible to segregate the milk which contains bacteria that survive pasteurization.

The Phosphatase Test for Pasteurization. This method is based on the fact that the pasteurization process, when properly carried out, will inactivate the enzyme, phosphatase, in milk. In milk which has not been heated to the required temperature or held for the time required for pasteurization, or in raw milk, the enzyme, phosphatase, is still active. This enzyme, if present, will liberate free phenol from alcoholic esters of phosphoric acid. This activity of the enzyme is measured in the phosphatase test. A rapid "field test" and a slower, but more accurate, laboratory method of the phosphatase test

have been developed.* The phosphatase test is very sensitive and will show very small variations in the time and temperature of pasteurization. As little as 0.1 per cent raw milk in pasteurized milk is also easily detected by this test. Therefore the phosphatase test is very valuable when used by laboratory control workers and milk inspectors for enforcement of pasteurization regulations.

Quality Control. The modern dairy company operates a laboratory to perform the tests heretofore described. Field men are employed to help producers make use of the results of tests on their supply, because only by having a high-quality supply can the processors make a high-quality finished product that will satisfy consumers. The Breed test for bacteria, the laboratory pasteurization test and sediment test are very valuable tests on milk as received at the platform. A member of the laboratory also acts as a quality control officer in the plant to see to it that laboratory results are put to work in making a safe finished product of high quality. Phosphatase, bacterial plate counts, acidity, sediment, and flavor tests are widely used.

The consumer judges dairy products almost entirely by flavor. It is very important that the quality control laboratory be staffed with one or more persons with a keen sense of taste and smell and who have been trained to recognize various off-flavors in dairy products, some of the most common of which are high acidity or sour, feed, barny, rancid, oxidized, salty, malty, and disinfectant. Most of these flavors need no further description. The oxidized flavor, which is quite common, may be due to the product's coming in contact with metals such as copper or iron or may be due to exposing milk to sunlight or strong daylight. In some instances certain cows produce milk that has this oxidized flavor. The disinfectant or medicinal flavor may come from materials used for sterilizing equipment or materials used for insect sprays.

QUESTIONS

1. Define bacteria and give some idea as to their size.
2. List the factors affecting the growth of bacteria.
3. State the temperatures at which bacteria thrive most readily.
4. What is the difference between pasteurization and sterilization?

* These tests, and the reagents required for them, are fully described in *Standard Methods for the Examination of Dairy Products,* 1953, 10th edition, published by the American Public Health Association.

5. What happens to bacteria when dried milk and water are mixed, and why?
6. What are the four different shapes of bacteria?
7. What types of bacteria are most commonly found in milk? Are any of these types useful?
8. What are the characteristics of milk in which gas formers have developed?
9. What do the liquefying bacteria do to milk?
10. What is particularly peculiar about the psychrophiles?
11. What are some of the diseases that can be spread by milk and which ones might be traced to the cow?
12. What are the major differences between bacteria and yeast and molds?
13. What is meant by the bacterial count?
14. What do high bacterial counts in milk indicate?
15. Outline the plate method for determining the bacterial count.
16. How is the bacterial count determined by the microscopic method?
17. What is the importance of the coliform organism test?
18. What are the common sources of the bacteria found in milk and which are likely to be the most prolific sources?
19. What are some of the types of abnormal milk caused by bacterial development?
20. How would you eliminate an epidemic of ropy milk?
21. What are bacteriophages and why is it important to know about them?
22. What are antibiotics used for and why may they be a problem for the dairy plant?
23. What are the two ways of expressing the acidity of milk; on what are they based?
24. How much acid is there in milk when it is drawn from the cow? How much when it begins to taste sour?
25. What are the conditions most favorable to the souring of milk?
26. Give five reasons why an acid test is needed.
27. If an acid test on a sample of milk is 0.24 per cent, what does it indicate to you?
28. Upon what principle does the acid test operate?
29. Outline, step by step, the operation of Manns' acid test.
30. Why does milk remain white when the indicator is added?
31. What is the importance of the rapid test for acidity?
32. Why is the use of the sediment test of value in the improvement of a milk supply?
33. Why does the methylene-blue reduction method indicate the bacterial content of milk?
34. State the principle on which the resazurin test operates.
35. What is the fermentation test and how is it done?
36. Why is the laboratory pasteurization test of such practical value?
37. Why is the phosphatase test so important?

PROBLEMS

1. What is the percentage of acid in milk if it takes 6.5 ml of Manns' solution to cause a pink color in 17.5 ml of milk? *Ans.* 0.325 per cent

2. How many pounds of acid are there in a 4,000-gal vat of cream, if a 17.5 ml sample required 8.1 ml of Manns' alkali to neutralize. Figure 1 gal of cream at 8.2 lb. *Ans.* 132.84 lb acid

3. A sample of cream is 0.4 per cent acid. How many milliliters of Manns' solution would be required to cause a pink color? *Ans.* 8 ml

4. If 500 lb of cream testing 0.3 per cent acidity are mixed with 2,000 lb of cream testing 0.15 per cent acidity, what is the acidity test of the mixture? *Ans.* 0.18 per cent

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CHAPTER **15**

Essentials in the Production and Handling of Milk on the Farm

Necessity of High Quality. Milk is nature's perfect food for infants. It is also a most important food for adults and is the most widely used of all foods. A further increase in the consumption of milk is to be desired, and the following facts must receive consideration:

1. Milk is very perishable.
2. Milk that happens to contain disease organisms spreads the disease rapidly.
3. Milk readily takes on bad flavors.
4. Since milk is white, dirt is easily seen in it.

Milk of high sanitary quality, therefore, must be:

1. Low in bacterial count.
2. Free from disease germs.
3. Of good flavor.
4. Free from dirt.

People are becoming more fully educated about these points, and there is a constantly growing demand for milk of high quality.

The conditions that have a possible relation to the points noted above are:

1. Kind of barn.
2. Kind of milk house.
3. Health of cow.
4. Health of attendants.
5. Feeding routine.
6. Preparation of cow for milking.
7. Preparation of milker.
8. Kind of milk pail.
9. Milking machine.
10. Promptness in removing milk from barn.
11. Straining or clarifying.
12. Cooling methods.
13. Method of cleaning utensils.
14. Fly control.

Of these fourteen factors, all may affect the bacterial count, but the ones that usually have the greatest effect are health of cow, kind of pail, use of milking machine, cooling milk, and cleaning utensils, with particular emphasis on the last two.

The principal factors that affect flavor are feeding routine and kind of feed, preparation of cow for milking, ventilation of stable, removal of milk from barn, and cleanliness of utensils.

The principal factors affecting sediment in milk are feeding routine, preparation of cow for milking, kind of pail used, and straining of milk.

Because milk sours as a result of the action of certain bacteria on milk sugar, the factors that affect bacterial count also affect acidity.

Requirements of a Good Cow Barn. The requirements are: (1) proper location, (2) plenty of light, (3) sufficient air space, (4) good ventilation, (5) proper floor, (6) proper tie, (7) smooth, tight walls and ceiling, (8) good method of disposing of the manure. The location should be free from contaminating surroundings, such as mud holes, pig pens, privies, and hen pens. There should be 4 sq ft of glass and 500 cu ft of air space per cow. Either a flue system or tilting or sliding windows, or some combination of these, should be used for ventilating. Poor stable ventilation not only has a direct effect on milk quality because of undesirable odors that the stable air may impart to the milk but also may affect the health of the cows and, hence, indirectly affect milk quality. A winter temperature of 40° to 50° F in the cow stable seems most desirable. The barn should be so constructed, and the ventilating system so con-

trolled, that the temperature will not go below 40° F. Extreme cold in the stable makes it necessary to feed more heavily to maintain normal milk production, and even then a decline in milk flow is likely to occur. Floors should be of concrete or other impervious and easily cleaned material. The gutter should be 14 to 16 in. wide and 8 to 10 in. deep. A space of at least 4 ft and preferably 5 ft should be left behind the cows and the stalls should be 4 ft wide and 4 to 5½ ft deep. It is a good plan to taper the row of stalls, having them, for Holsteins, 5½ ft at one end and 5 ft at the other, and for the other breeds, 5 ft at one end and 4 ft at the other. This permits placing the young stock at the short end and the mature animals at the other. Swing stanchions make the best tie, and keep cows up on stall floor so that manure is dropped into the gutter. Walls may be made of masonry, or they may be plastered or sheathed with wood. They should be tight and easy to clean. Ceilings should be of tight and smooth construction. Manure should not be piled up near the barn, and all over the cow yard, but should be removed to a pit or to the fields. All this does not mean that a separate barn for cows is necessary, or even advisable under ordinary conditions. The two-story barn with plank frame construction, having hip roof, is still a very practical structure.

Fig. 76. Exterior of good cow barn and milk house with desirable surroundings.

Fig. 77. Interior of modern cow barn.

The Milk Room or House. So that the milk can be removed from the barn, as should be done, a milk room or house must be provided. Almost all the larger cities and important milk companies require a milk house, so the producer in most cases must have one. What has been said about the location, construction, and so on, of the barn also applies here. The milk house should not be too large, and should be used for milk only, not for tools or other articles. It should be screened in summer.

When bottled milk is sold directly from the farm, the milk house should have at least two separate rooms, one for handling the milk and the other for washing utensils. A most convenient and practical arrangement is to have the milk house attached to one side of the barn, where prevailing winds will not blow odors from the stable and barnyard into it. It should be attached at about the center of the barn by means of a covered alleyway. The milkers step into this alleyway through swinging doors opening from the barn. In the alleyway the milk is weighed and strained into a small tank from which it runs immediately through a partition and over the cooler into the milk-handling room. The milk room should have a concrete floor, smooth walls and ceiling, and should be kept strictly clean.

Fly Control. There are two major reasons for good fly control. First, flies may annoy cows to the extent that milk production is decreased and, second, flies are a source of large numbers of very undesirable bacteria. Flies breed rapidly in filth. It is, therefore, obvious that the all-important step in fly control is to practice sanitation in the barn and milk house and around the premises. This means keeping all areas in the barn free from manure, and instead of allowing manure to accumulate in the barn yard, removing it to the fields daily. Milk houses should be screened. Waste disposal containers should be kept covered and cleaned after emptying.

Residual sprays, sprays that adhere to surfaces where flies congregate and continue to be effective for long periods of time, will be found helpful. Extended use of certain sprays may cause flies to become tolerant, in which case the spray ceases to be effective. However, new sprays are being developed frequently, and the county agent will be in a position to make the proper recommendation. The same can be said of space sprays, mists sprayed into the air, the lasting effect of which is totally undependable. Sprays should be resorted to only after a good job of sanitation is done, and directions for use that come with the sprays should be followed carefully.

Health of Cow. The possible ill effect on human health of milk from a sick cow indicates how important it is that all cows be in good physical condition. One cannot feel safe in giving milk to a child unless it comes from animals known to be free from disease, or unless it has been pasteurized.

Good herd management also demands that a herd be kept free from disease. Studies have shown that the monetary profits from diseased herds are decreased 15 to 25 per cent. Herds should be tested for and kept free of such common diseases as tuberculosis, brucellosis, and mastitis. Before dairy cattle are bought, they should be tested and found free of these diseases, which in the past have been the most troublesome.

Health of Attendants. Because the bacteria that cause most of the diseases spread by milk come from human beings, it is easy to see the great importance of making sure that everybody who milks the cows or handles the milk or utensils is in good health. It must be remembered that most of the disease epidemics that have been traced to the milk supply have been of human origin. A single milk-borne epidemic may not only seriously curtail the business of the milk dealer in question and have a general depressing effect on milk

consumption, but also may result in considerable loss of life. One who feels ill or who is not careful about his personal hygiene is an undesirable risk as a dairyman. A dairyman may be a carrier of disease, such as typhoid fever, and not know that he is endangering human life unless he submits to a medical examination.

Feeding Routine. To make sure that the milk is free from feed flavors, it is desirable that nothing be fed just before or during milking. This is particularly true of such feeds as silage, turnips, and cabbage. Although these feeds may affect the air in a poorly ventilated stable in such manner as to influence the flavor of the milk,

TABLE 30. INFLUENCE OF FEEDING HAY, GRAIN, AND CORN STOVER JUST BEFORE MILKING ON THE BACTERIAL CONTENT OF MILK[a]

	Bacteria per Milliliter		
	Total	Acid Producing	Liquefying
Before feeding	2,096	790	108
After feeding hay and grain	3,506	1,320	196
Increase caused by feeding	1,410	530	88
Before feeding dry corn stover	1,233	297	1
After feeding dry corn stover	3,656	692	28
Increase caused by feeding	2,423	395	27

[a] Hammer and Babel: *Dairy Bacteriology*, 4th edition John Wiley & Sons, New York, 1957.

it is well known that the principal source of these feed flavors is the cow's system, that is, the feed flavor passes through the cow's system and into the milk a very short time after the food is eaten. Dusty feeds should not be fed just before milking, as the air may thereby be filled with dust and bacteria. Though not so much dust nor so many bacteria get into the milk as was once supposed (see Table 30), some do get in and are likely to be objectionable gas-formers.

In some sections of the country wild onion, garlic, or other weeds constitute a real pasture problem. If cows eat these weeds within 1 to 4 hours of the time of milking, the resulting milk may have such strong weed flavor as to be unfit for use. Pasture renovation and clipping of weeds, giving the more tender grass a chance to grow, will help the situation, but taking cows from this type of pasture about 3 hours prior to milking is the best practice during the weed seasons.

Preparing the Cow. The cow should be curried and brushed once a day, if possible. Before milking, the udder and flanks of the cow should be thoroughly brushed; and just before milking each cow, the udder should be wiped with a cloth or paper towel moistened in warm water. The importance of this practice is shown in Table 31. Clipping the flanks of the cow makes it easier to keep her clean. Wiping the udder with the hands before milking is a very bad practice, as it does not get the udder clean, but does get the hands dirty. An old, dirty, dry cloth does little good. Washing the udder and wiping dry, although ideal, is not practical or necessary under ordinary conditions, unless the udder is covered with mud or otherwise badly soiled.

TABLE 31. EFFECT OF WIPING THE UDDER ON THE BACTERIAL CONTENT OF MILK[a]

	Bacteria per Milliliter		
	Total	Acid Producing	Liquefying
Udder and flank not wiped	7,058	3,554	81
Udder and flank wiped	716	185	47
Decrease due to wiping	6,342	3,369	34

[a] Hammer and Babel: *Dairy Bacteriology*, 4th edition, John Wiley and Sons, New York, 1957.

Preparing the Milker. The milker should wear clean, sweet-smelling clothes, and should wash his hands as often as they become soiled. White clothes are recommended because one can tell easily when they are soiled; it is also in harmony with the color and nature of milk. The clothes of the men handling the milk after it is strained should be clean, and sweaters should not be worn as outside garments, because the wool fibers may be rubbed off into the milk.

Kind of Milk Pail. A small-mouth pail should be used, as experimental data and common sense tell us that a large percentage of the dirt on the body of the cow and the bacteria attached thereto will be kept out of milk drawn into a pail with its top partly covered (see Table 32). The main reason why small-mouth pails are not used more generally is that the advantages of the small-mouth pail are

not understood. In many cases, open pails have been used on the farm for generations. Small-mouth pails are somewhat difficult to milk into at first, but one can quickly adapt oneself to this obstacle. The pail with an elliptical opening of about 7 by 5 in. is the most practical and the easiest into which to milk. Small-mouth pails require more care when being washed, however. It is for this reason that many dairymen still prefer the open top pail.

TABLE 32. INFLUENCE OF SMALL-TOP MILKING PAILS ON THE BACTERIAL COUNT[a]

Conditions	Bacteria Per Milliliter	
	Open Pail	Small-Top Pail
Cows dirty, utensils sterilized	86,212	24,439
Cows dirty, udders and teats washed, utensils sterilized	6,166	2,886
Cows clean, udders and teats washed, utensils sterilized	4,947	2,677

[a] Kelly and Clement: *Market Milk*, John Wiley and Sons, 1931 (out of print).

Use of Milking Machines. The milking machine is used now almost universally. The use of the milking machine will be discussed here only as it affects the sanitary quality of milk. If the cows are prepared for milking in the same manner as when hand milking is practiced, there is reason to expect that the machine-drawn milk will be freer from dirt than hand-drawn milk. There is no chance for dirt to get into the milk that is drawn into the machine bucket, but when the cows are stripped the milk gets very dirty if the cow is not clean. The same precautions should be taken as in hand milking, and stripping should be done with a small-mouth pail or be done by means of machine stripping.

It is not as easy to produce milk of low bacterial count with a machine as it is with hand milking, because the machine parts must be carefully washed and sterilized. This is often so imperfectly done that the milk becomes badly contaminated with bacteria. This problem is shown in the following figures from the Storrs, Connecticut, Experiment Station. The average count in 14 machine-drawn samples from 11 different farms was 433,073 per ml, as against 61,800 per ml for 119 samples which included the 14 machine-drawn samples, the others being hand-drawn. With proper care, milk of low bacterial count has been and can be produced with the machine. The methods of cleaning are as follows:

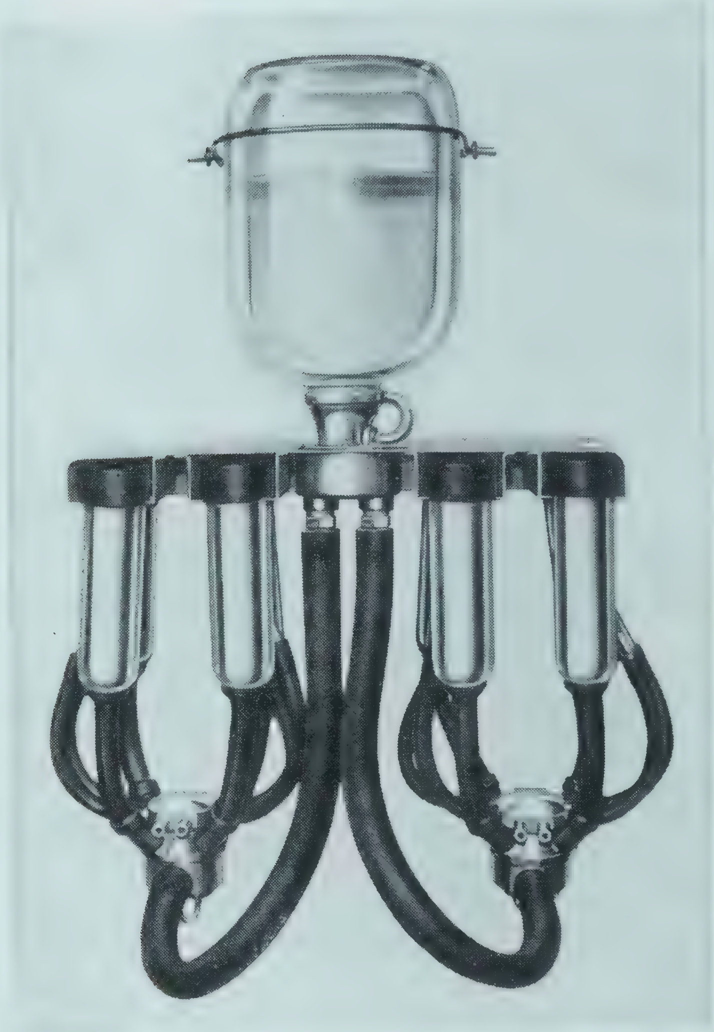

Fig. 78. De Laval solution rack.

CHEMICAL METHOD. (1) Draw clean, cold water through teat cups and tubes. (2) Follow with hot water containing a dairy cleanser. (3) Follow with clean, hot water. (4) Douse tubes up and down in water, so as to draw, alternately, water and air through them. (5) Wash all dirt from the outside of the teat cups and tubes before putting into sterilizing solution.

(6) Take a 20-gal stone crock and fill to within 5 or 6 in. of the top with clear, cold water. Add salt to water until a saturated solution is formed. Add to this water some hypochlorite sterilizer, following directions on package, or, better still, make up some chloride of lime solution (12-oz can to gallon of water) and add a quart to the crock once a week in winter and twice a week in summer. Make

up a fresh solution as often as the old one begins to get milky. Caustic soda solution can be used instead of the chlorine solution described. This solution can be made by dissolving a 12-oz can of household lye in a gallon of clean water in a gallon bottle. This mixture makes a 10 per cent solution of caustic soda. When ready to use, 4 fluid oz of the solution are added to each gallon of water needed.

(7) In putting the teat cups and tubes into the crock, hold the tubes up straight, so that no air may become entrapped. Plug the air tubes.

There is one serious objection to this method, which is the using of the sterilizing solution over and over again. These solutions get dirty and lose their strength and as a result are a source of contamination rather than a sterilizer. An arrangement whereby the sterilizing solution can be used only once is much more satisfactory. Such a rack, put out by the De Laval Separator Company, is giving excellent results.

HEAT METHOD. (1) Proceed as in chemical method, up to drawing cleanser solution through tubing when teat cups and tubes are brushed out. (2) Place in a tank of water, heat to 160° or 170° F, and hold for 15 to 30 min. Use live steam or flame.

(3) Leave in this water (covered) until next milking. Note: This method is very effective. The tubing of some machines stands the heat better than others, and there is a difference in tubing obtained from the same company at different times.

(4) In either method, wash teat cups and tubes thoroughly with brushes and washing soda twice a week. (5) Buckets must be washed and sterilized in the same manner as the milk pail. Improperly cleaned machine parts, especially the rubber parts, may seriously affect the flavor of milk. On large dairy farms, the pipeline milker is extensively used. The milk is drawn directly from the cow's udder into a sanitary pipeline, generally located over the top of the stanchions. The line conveys the milk through a filter direct to cans, a cooler, or cooling tank. On some farms, this system is used in connection with a special milking room or "parlor" as it is sometimes called. The cows are let into this room, one or a few at a time, depending on the size of the operation. A loose housing system, whereby the cows wait on themselves by self-feeding of roughages is frequently used with this system of milking. Concentrates are fed as the cows are milked in the milking parlor. It is said that up to 30 per cent of chore time can be saved for the dairyman using this plan.

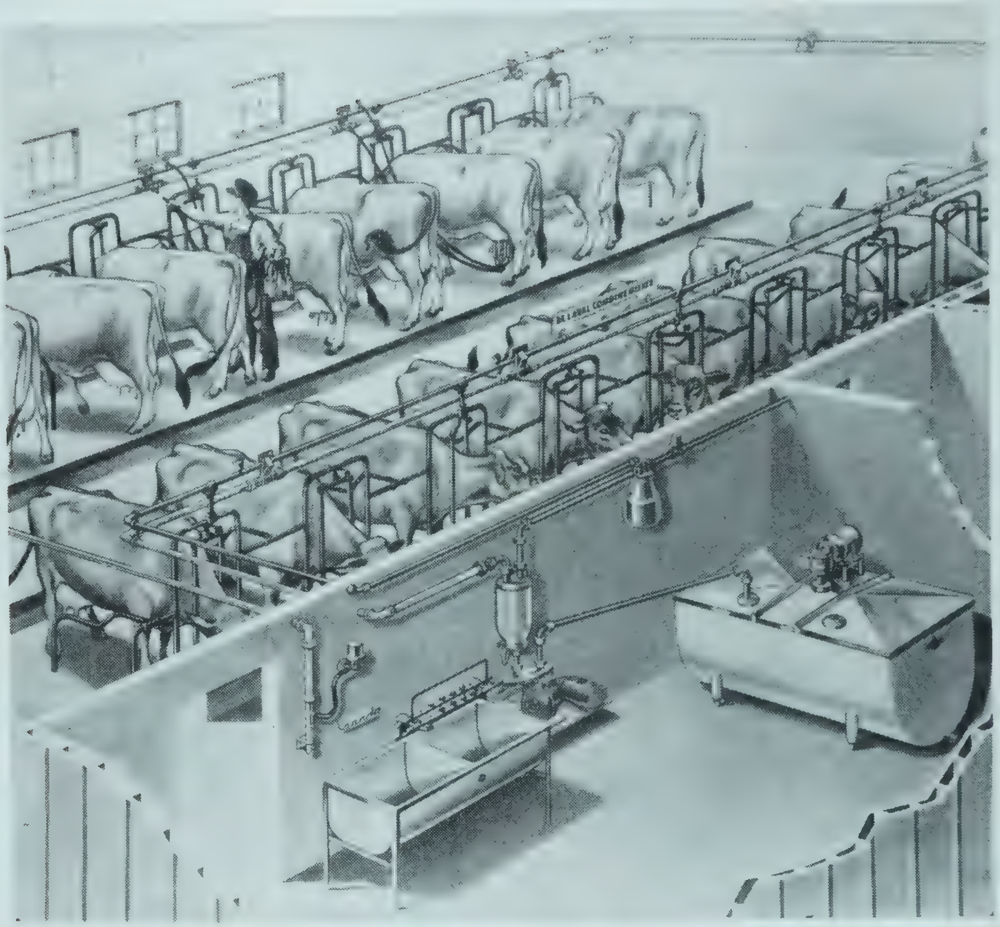

Fig. 79. Pipeline milker setup. (Courtesy De Laval Separator Co.)

Cleaning Utensils. Like the milking machine, unclean and unsterile utensils are the source of most of the bacteria that get into milk. This fact is plainly shown in Table 33. Here is a case of an excellent grade of milk spoiled by improper handling. A milk utensil, to be properly cleaned, should be (1) rinsed in cold or lukewarm water to remove the bulk of milk sticking to it, (2) washed in a warm dairy cleanser solution, with a brush, never with a rag. A brush gets dirt out of any imperfectly soldered seams, while a rag simply smooths it over. After this, (3) the utensil should be rinsed in scalding water. To make it really sterile, the utensils should then be steamed or chemically sterilized. So-called scalding of utensils is effective if the water is near boiling and the utensils can be left in the water for 2 or 3 minutes.

Water that one can hold his hand in does little good, as it is not hot enough. Many farms have small boilers and use live steam.

Sometimes utensils are steamed over a steam jet. This method is fairly effective if the utensil is left over the jet from 30 seconds to 1 minute, so that it is heated and will dry out readily. A steam chest, which may be built of almost any material, provides the most effective means of steaming. Steam is admitted and a temperature of 210° F is maintained for half an hour.* Where the steam chest method is not used, utensils should be exposed in a clean, airy place, to dry out after sterilizing. The drying is an important part of the process, as any bacteria that escape sterilizing will begin to multiply in a moist utensil.

TABLE 33. EFFECT OF UNSTERILE UTENSILS ON THE BACTERIAL COUNT IN MILK[a]

Condition of Utensil	Bacteria, Per Milliliter
Sterile utensils	5,000
Unsterile utensils added:	
Three pails	54,159
Strainer	7,315
Clarifier tank	8,038
Clarifier	141,340
Cooler	50,900
Bottle filler	83,248
Total	350,000
From unsterile utensils	345,000

[a] *Illinois Bull. 204.*

The chemical sterilization of dairy utensils is meeting with considerable favor throughout the dairy industry. The various chlorine compounds are used in varying strengths: 50 to 100 parts of active chlorine to a million parts of water for rinsing; 70 to 100 parts to a million for dipping, and about 200 parts to a million for spraying. The solution should come into contact with the utensils for at least 10 seconds, and it should be emphasized that these chemical sterilizers are not effective or satisfactory unless the utensils are absolutely clean. Directions for mixing the solutions will be found in Appendix G.

Removal of Milk from Barn. The milk should be removed from the barn after each cow is milked, to insure its being free from a "cowy" flavor. This is particularly important in a poorly ventilated barn.

* A more effective sterilizer, designed for use on a small scale, is described in *U.S.D.A. Farmers' Bull. 740.*

Straining Milk. The fact that milk is to be strained is no excuse for letting dirt get into it. The object of straining is to remove any dirt that may have dropped into the milk in spite of the care observed. Good straining materials are outing flannel, four thicknesses of cheese cloth, and absorbent cotton. Of these materials, the cotton pad is the best. It is required by many city health departments principally because it is efficient and can be used only once. The more recently developed outing flannel disks or squares are proving very satisfactory and, in some ways, at least, are to be preferred to the cotton pads. The dirty strainer cloth is a serious source of contamination; this means that, if a strainer is to be used more than once, it should be carefully washed and boiled out or steamed. Fine wire mesh strainers, as a rule, are not very satisfactory.

Cooling Milk. The following table shows the necessity of cooling milk to prevent bacterial growth. A quantity of milk was divided into 6 parts, and each part was exposed to a different temperature for 10 to 11 hours.

Regardless of how many bacteria may be introduced into the milk, if it is cooled to 50° F or below, growth takes place very slowly. A large percentage of the bacteria in milk, when it reaches the con-

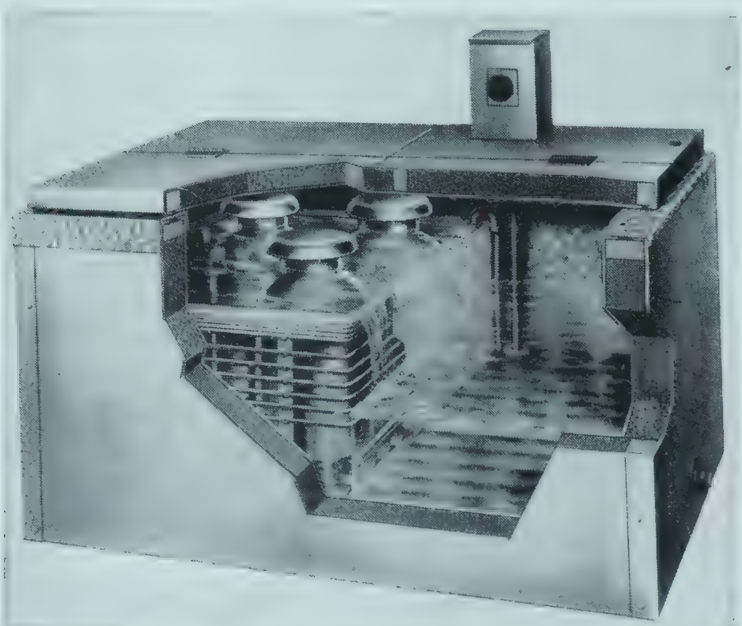

Fig. 80. Cutaway view of a mechanical milk cooling tank. (Courtesy of Esco Cabinet Co.)

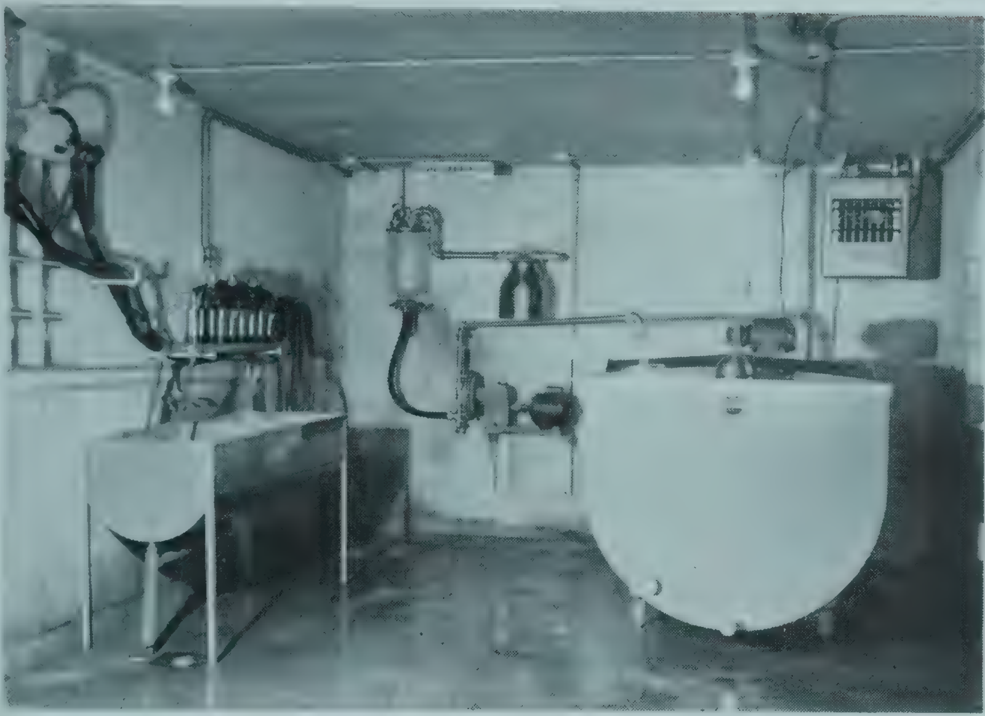

Fig. 81. Bulk cooling and storage tank. (Courtesy De Laval Separator Co.)

sumer, is the result of multiplication due to improper cooling and not to original contamination. Milk should be cooled to at least 45° to 50° F as soon as possible after milking, at least within 2 or 3 hours.

TABLE 34. EFFECT OF TEMPERATURE ON BACTERIAL GROWTH[a]

Temperature of Milk ° F.	Time Held (hours)	Number of Bacteria Per Milliliter
32	10	3,000
50	10	11,580
60	10½	15,120
70	11	188,000
80	11	2,631,000
90	11½	4,426,000

[a] *Nebraska Bull.* 133.

When milk is sold in bottles, the quickest and most practical method of cooling is to use a milk cooler. There are three general types of coolers on the market, the external tubular, the external

conical, and the internal tubular. The first two work on the same principle, that is, the cooling medium enters the cooler at the bottom and comes out at the top, while the milk flows in thin sheets over the outer surface. For cooling small amounts of milk or cream, a hollow conical cooler, in which is placed ice water that can be stirred as the milk flows over the outer surface of the cooler, is the practical type to use. The other types must be attached to a supply of running water, or a pump must be used to circulate the water. Tubular coolers are commonly made in two sections, the top set of coils being for water and the bottom set for ice water or brine. The use of the internal tubular cooler is confined almost entirely to the milk plant. This cooler is composed of sets of pipe coils, the milk pipe being surrounded by the water pipe. The milk and the cooling medium flow in opposite directions. All types of coolers must be carefully cleaned and kept in an atmosphere free from dust and flies, as otherwise they become a prolific source of bacteria.

Milk shipped to processing plants is cooled in the cans in which it is shipped or in so-called bulk tanks. This method requires cold water (below 50° F) or ice water, and for cooling in cans a properly constructed cooling tank. The following points should be observed in constructing cooling tanks and cooling milk in them:

1. Build the tank of insulated concrete, plain concrete, or wood. Insulation pays for itself in one season.
2. Make it deep enough to permit water to come up around neck of can.
3. Have the inlet and drain at the bottom.
4. Sink bottom of the tank from 1 ft to 1½ ft below the level of the ground.
5. Have the tank covered.
6. Put a rack in the bottom of the tank 2 to 3 in. from the bottom, in order that the water may circulate under the cans.
7. Make one large and one small compartment to allow for varying production.
8. The tank should hold 4 gal of water to each gal of milk to be cooled.
9. Use 4 lb of ice to cool each gal of milk.
10. Provide 1½ to 2 tons of ice per cow annually for cooling milk.
11. Keep the tank clean.

In the past few years rapid steps have been made in the development of mechanical refrigeration units for cooling milk. The producer can build his own tank and install the refrigeration unit, or

purchase a tank and unit complete. The tank ought to be large enough to hold at least 2 gal of water for every gal of milk. It should also be well insulated. The size of the unit must be sufficient to build up a reserve ice supply and thus avoid excessive drains on the capacity of the compressor at any given time. The cost of cooling milk this way compares favorably with ice cooling, and the results are very satisfactory.

Since about 1950, the cooling of milk in bulk tanks has been increasing rapidly. The bulk tank is of stainless steel construction. The jacket of the tank is built for direct expansion or cold water circulation as the cooling medium. The tank is covered, and there is provision for a motor driven agitator and a metal measuring "stick" for measuring the milk. The tank must be built so that it will drain completely. The measuring device must be accurately calibrated. It should be designed so as to cool 50 per cent of the rated capacity of milk in the tank to at least 50° F within 1 hour after milking and to at least 40° F within the second hour. There are many companies building these tanks in a variety of shapes and sizes. One must take future expansion plans into consideration when buying a tank. A rule-of-thumb guide is to buy a tank that will hold 3 milkings during the flush season for every day pick-up of milk and 5 milkings for every-other-day pickup.

The procedure in using the bulk tank is as follows:

1. After a small amount of milk has flowed into the tank during milking, the refrigeration is turned on and the agitator is started and kept going until milking is completed and the milk is cooled to at least 40° F.

2. At the next milking, the operation is repeated.

3. The company hauler arrives during the day with an insulated, stainless steel pickup tank, equipped at the rear or on the side with a cabinet for pump, plastic hose, and sample containers.

4. The truck is pulled up close to the milk house and the hauler reads on the measuring stick scale the amount of milk in the bulk tank and starts the tank agitator; in the meantime he connects hose from the pickup tank to the bulk tank. The milk is then sampled for butterfat and for periodic bacterial counts. The odor of the milk is noted. The hauler, who must be trained by the milk company to grade, measure, and sample milk, must be licensed in many states.

5. The milk is pumped into the pickup tank. The producer gets a copy of the milk measurement record and the hauler proceeds to the next farm.

6. The producer rinses, washes, rinses, and sterilizes his tank to prepare it for the next milking.

Circular 510 of the University of Wisconsin Extension Service lists the following balance sheet for the use of bulk tanks:

Advantages of Bulk Milk for Producer and Hauler

1. Milk quality is protected, due to the prompt and excellent cooling ability of farm bulk tanks.
2. Milk quantity is determined at the farm. The farmer can check the measurement of milk.
3. Less milk may be lost due to milk sticking in cans, since they are normally dumped at the plant.
4. Adequate agitation of milk in tank enables representative sampling for butterfat and milk quality. (Two minutes has proved to be long enough for both butterfat and bacteriological sampling.)
5. Cans are eliminated with resulting savings in initial and retinning cost of cans. Work is saved in handling, washing, rinsing, sanitizing, racking, and lifting cans.
6. Time is saved and work is somewhat easier. There are no full cans to handle, although milk may have to be lifted higher with certain bulk tanks unless the producer has a C.I.P. (cleaned-in-place) pipeline milker. There is no waiting for cans to get full before transferring the strainer to the next can. Incidentally, the bulk tank, along with C.I.P. pipeline milking saves the most time and labor. It also permits the operator to remain with the milking machines while milking.
7. It may be possible to handle a larger volume of milk without enlarging the milk house.
8. It is easier work for the milk hauler.
9. Farmers report more home use of milk.
10. The producer pays closer attention to milk quality because of the danger of losing an entire tank of milk.

Objections to Bulk Tanks Most Often Raised by Producers

1. High initial cost of coolers, especially for small producers.
2. Farmer has to wash and sanitize bulk tank (though most farmers who have tried it agree that this is an easy job that need not take more than 10 minutes).
3. Some changes usually are needed in the milk house and yard around it—for example a concrete slab or apron next to the milk house, a port opening for milk hose and a 240-volt electrical outlet

for the milk pump on the tank truck, and a solid milk house floor that will not settle or heave.

4. Producer failure to pay close attention to milk quality may cause the loss of an entire tank of milk instead of only a can or two.

Advantages of Bulk Milk in Receiving Plant

1. Can receiving equipment is not needed if plant does not need can washer for other cans.
2. Less plant labor is needed.
3. Lower plant utility costs are possible.
4. Better cooling protects milk quality.
5. Every-other-day pickup is being widely used and can further reduce costs on markets where it is accepted.

Disadvantages of Bulk Milk in Receiving Plant

1. Higher qualifications and special training are required for milk haulers.
2. Truck washing facilities are needed in the plant.
3. Because fat and quality samples must be taken on the farm, plants must depend on haulers for inspection of the milk.
4. Initial cost of bulk pickup tanker is greater than for a truck for cans.
5. Any loss of milk between the farm and the receiving room is at the plant's expense.
6. Plant changes may be required.
7. Work in handling samples is increased.

QUESTIONS

1. Why does the consumption of milk depend on the way the milk is handled?
2. What are the specifications for a high-quality milk?
3. What handling conditions have the principal effect on the bacterial count?
4. What are the principal factors that affect the flavor of milk?
5. What are the principal factors that affect the amount of foreign material found in milk?
6. What are the major requirements of a good cow stable?
7. Why does the Holstein cow need a longer stall than a Jersey cow?
8. What are some of the major specifications for a milk room or milk house?

9. Why is a healthy cow so important in the production of high-quality milk?
10. What are the three major diseases of dairy cattle?
11. Why is the health of the milker and milk handler so important?
12. What feeds should not be given during milking?
13. How would you prepare the cow for milking?
14. How would you prepare yourself for milking?
15. What type of milk pail should you use and why?
16. Why is unusual care necessary in producing milk of low bacterial count when the milking machine is used?
17. What are the essential points in cleaning and care of the milking machine?
18. What are the steps to take in cleaning utensils?
19. What are the methods of sterilizing utensils?
20. Why is it important to remove milk from the barn as soon as it is drawn from the cow?
21. What is the importance of straining milk and how is this done?
22. Why is the cooling of milk and keeping it cold so important?
23. What are the common methods of cooling milk?
24. What are the essentials in the construction and use of the cooling tank?
25. What is meant by the "bulk tank" system of handling milk?
26. What are the steps in the use of the bulk tank?
27. What are some of the advantages of the bulk tank for the producer and hauler?
28. What are objections sometimes raised by producers?
29. What are the advantages of the bulk tank for the receiving plant?
30. What are the disadvantages of the bulk tank for the receiving plant?

PROBLEMS

1. A man has a herd of 12 cows, which gave in one year:

	Pounds of Milk	*Per Cent of Butterfat Test*
1.	9,048	3.8
2.	6,842	4.8
3.	4,670	4.0
4.	5,006	3.2
5.	3,645	5.0
6.	8,263	3.4
7.	3,972	3.7
8.	6,521	5.3
9.	6,640	4.3
10.	7,657	4.1
11.	5,836	3.9
12.	11,486	3.5

(*a*) What is the average number of pounds of milk per cow?
(*b*) What is the average number of pounds of butterfat per cow?
(*c*) What is the average percentage of butterfat in the milk of the whole herd for the year?

Ans. (*a*) 6,632.16 lb; (*b*) 267.00 lb; (*c*) 4.02 per cent

2. In number 1, what is the difference in value of the milk produced by the poorest cow in butterfat production and that produced by the best cow in butterfat production, on a butterfat basis, with butterfat at 72 cents per lb? *Ans.* $183.63

3. In number 1, what is the difference in value between the milk produced by the best cow in milk production and that produced by the poorest cow in milk production, with milk at $8\frac{1}{2}$ cents per qt? *Ans.* $309.99

4. In number 1, how much higher would the average production of the herd have been if (*a*) the poorest cow in quantity of milk and (*b*) the poorest cow in quantity of butterfat had not been in the herd?
Ans. (*a*) 271.56 lb milk
(*b*) 10.91 lb butterfat

5. In number 1, divide the herd into four parts according to the production of milk. What would have been the increased value of the product if the three poorest cows had been replaced by cows giving as much milk as the average of the three best cows? (Milk at $8\frac{1}{2}$ cents per qt.) *Ans.* $652.72

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CHAPTER **16**

Dairy Processes Common to a Number of Operations

Cream Separation. OBJECT OF SEPARATION. In order to get the butterfat in milk into a more concentrated form for churning and other purposes, it is separated, in the form of cream, from a portion of the milk serum. It is possible to separate cream from milk because of the difference between the specific gravity of butterfat and that of the other milk constituents. The specific gravity of milk serum is about 1.036, meaning it is 1.036 times heavier than water at the same temperature, whereas the specific gravity of butterfat is 0.93, or lower than water, which has a specific gravity of 1. If it were not for this fact, our present-day methods of separation would not be possible. In the early days of the industry cream was separated by gravity by allowing milk to set in shallow pans or in cylindrical cans having a glass gage and faucet near the bottom. The cream was skimmed off the pans or the skim milk was drawn off from the bottom of the cans. This was laborious, cream was of inferior quality, and much of the butterfat remained in the skim milk. Today cream is separated by centrifugal force, using a cream separator.

PRINCIPLE OF CENTRIFUGAL SEPARATION. The whirling force generated in the separator bowl is many times stronger than the force of gravity. This force draws the lightest part of the milk, namely, the butterfat in the form of cream, into the center of the bowl. The skim-milk layer is thrown out near the wall of the bowl, and sediment, being heaviest of all, is thrown to the extreme outer edge, where it

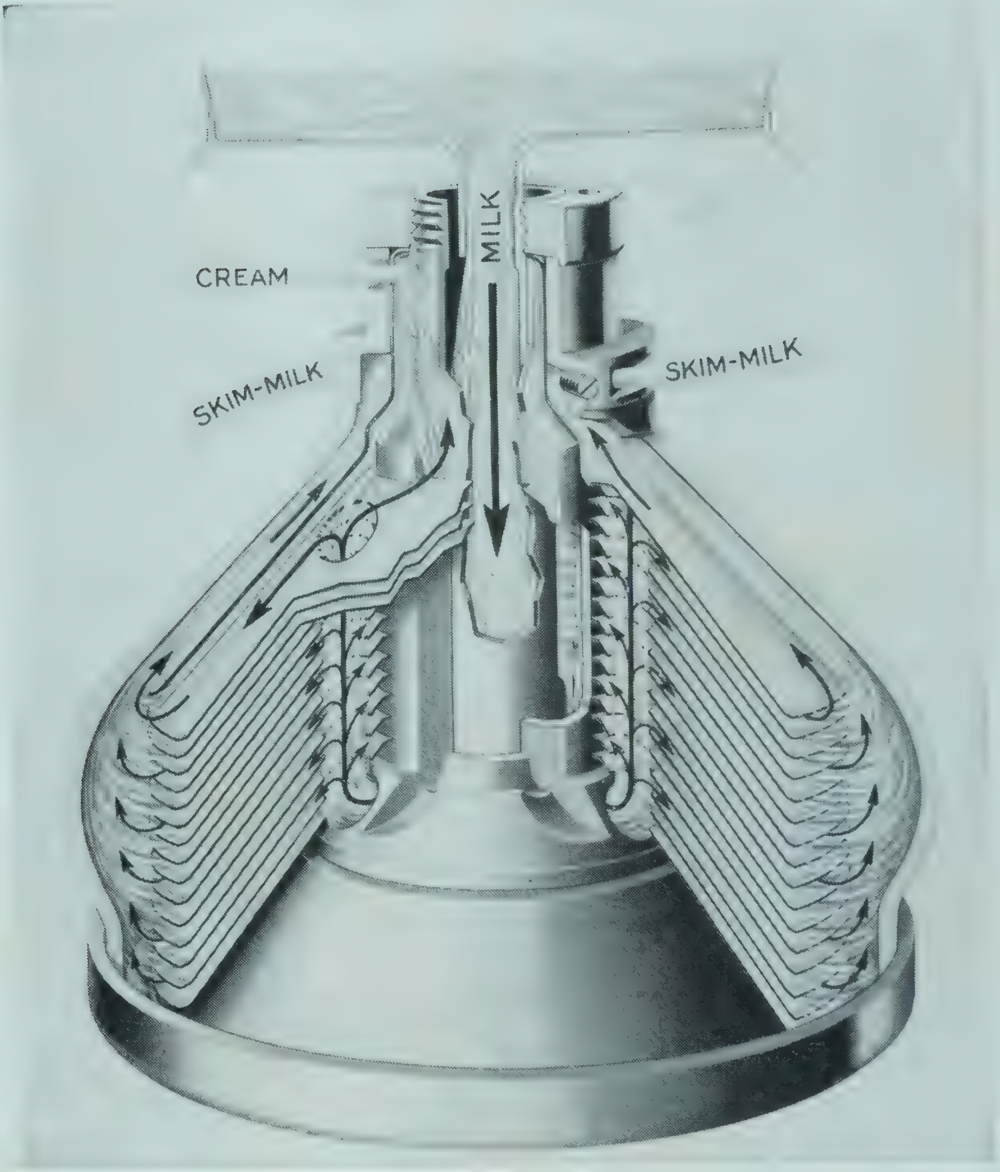


Fig. 82. The course of milk through a separator bowl. (Courtesy De Laval Separator Co.)

adheres to the wall of the bowl in what is called separator "slime." Separators are made in farm and factory sizes, and may be run by hand or power. Small machines skimming 150 to 200 lb of milk an hour, and various sizes up to those with a capacity of 25,000 lb per hour, are available to meet the needs of all. The trend today is away from the separation of milk on the farm to the separation in the dairy plant.

ADVANTAGES OF SEPARATORS. The development of the separator has been a tremendous aid in the growth of the dairy industry. The following are some of the advantages it possesses as compared with the other methods of creaming, and some of the things the separator has accomplished: (1) it is adapted to herds of any size; (2) it skims thoroughly, so that only 0.05 per cent or less butterfat is left in the skim milk; (3) it takes less time to get cream; (4) fewer utensils are needed; (5) less refrigeration is required; (6) the skim milk is fresh and warm, and in an ideal condition for calf-feeding; (7) one can skim a smooth cream of any richness desired; (8) the cream is

Fig. 83. Hand separator; sectional view. (Courtesy De Laval Separator Co.)

free from dirt, as the separator also acts as a clarifier; (9) it has made the farmer more independent as to a market.

AIRTIGHT SEPARATORS FOR FACTORY USE. The airtight separator is an improved machine for the separation of milk. It is so named because it operates in a hermetically sealed system in which milk is fed to the machine directly through a closed connection and cream and skim milk are discharged through similarly closed connections. The following advantages appear to result from this method of separation:

1. Keeping the milk from contact with air results in improved sanitation.
2. It prevents loss of product by delivery of both cream and skim milk free from foam.
3. It is not necessary to install the machine at an elevation because the cream is not discharged by gravity.
4. Because the cream is not discharged violently from the bowl, a more viscous, even-bodied cream is obtained.
5. The percentage of butterfat can be regulated while the separator is in operation. Cream testing up to 80 per cent butterfat may be produced.

The design of the airtight separator is shown in Fig. 84. The milk enters at the bottom of the machine and the skim milk and cream are removed from the top. Hoists are provided to facilitate the handling of bowls in the larger units.

Two types of airtight separators, namely, "warm milk" and "cold milk," are in use. Warm milk (80° to 90° F) separators are used more commonly in plants making manufactured products. These separators will operate at greater capacities and give more trouble-free operation. The skim milk should test 0.01 per cent or less by the Babcock test.

The cold milk separator is used more commonly in the market milk plant, as it is more flexible for the various operations. The cold milk separator will skim "clean" at 40° to 45° F but only at about one-half the capacity of its warm milk counterpart. A cream of improved viscosity is produced, heating costs are saved, less equipment is needed, and less labor is required for cleaning, thereby effecting further savings.

THE CARE AND OPERATION OF THE SEPARATOR. In putting the machine together, care should be observed not to drop the parts, or to dent them. The parts never should be crowded together. The machine will go together easily if the parts are in proper order. The

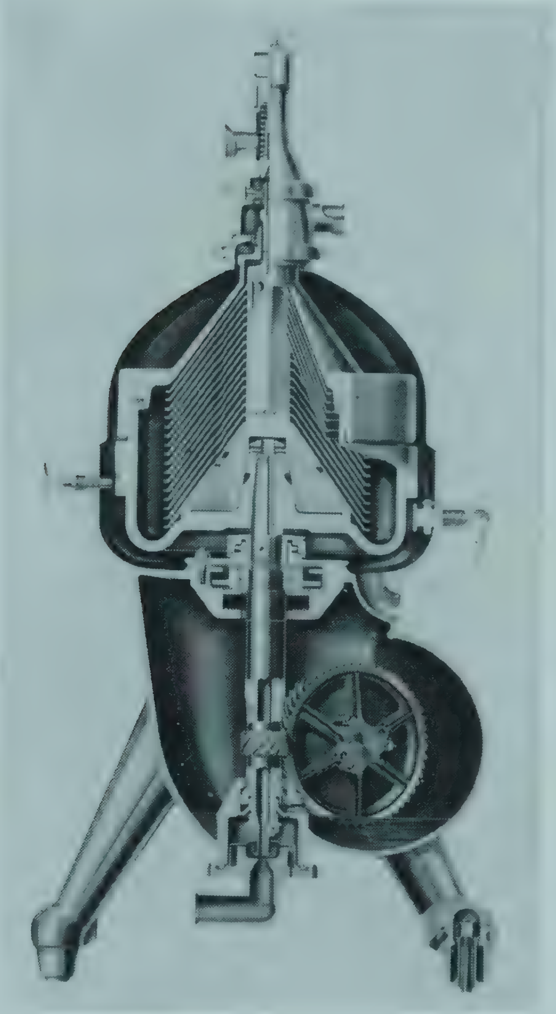


Fig. 84. Airtight power separator; sectional view. (Courtesy De Laval Separator Co.)

separator always should be kept well oiled. Most machines are oiled by a combination sight feed and splash oiling system. The separator should be brought up to speed gradually. It is a good plan to fill the bowl of a big power machine with water, to steady it in coming up to speed. Some machines are provided with speed indicators of various sorts, to make it easy to tell when it is up to speed. Sour milk or milk that is turning sour cannot be separated, as it soon will clog the machine. The milk should be let in only after the machine is up to full speed, and the machine should be kept at its rated speed. After the last milk is out, the power is shut off and the bowl flushed out with warm water until the discharge

from the cream spout looks watery. After the machine stops, the oil is shut off, the bowl taken apart, and the slime scraped out. All parts are washed and sterilized and the separator is ready to be used again.

FACTORS AFFECTING THE RICHNESS OF THE CREAM AND THE LOSSES OF BUTTERFAT IN SKIM MILK FROM SEPARATORS. It is important to understand these factors, particularly in the operation of the separator on the farm.

1. *Position of the cream or skim milk screw.* In some separators the cream comes out of a fixed opening and the skim milk comes out through an opening the size of which can be varied. In other machines, the reverse is true. Because centrifugal force causes the butterfat to be nearest to the center of the bowl, it is obvious that the nearer the center of the bowl the cream can be made to escape, the richer the cream will be. Therefore, when the skim milk comes out through an opening, the position of which can be changed, the cream will be richer when the skim-milk opening, or screw as it is called, is turned out. When the skim-milk screw is turned in, the cream is made thinner. When the cream screw regulates the richness, turning the screw in makes the cream come out nearer the center of the bowl and gives a richer cream; turning the screw out gives the reverse.

2. *Speed of the machine.* Separators are made to skim clean at a rated speed. With hand machines, there is some danger of turning the crank too slowly. This slowness results in more and thinner cream and higher-testing skim milk. If the machine is turned too fast, the cream is less in amount and richer. The test of the skim milk is not affected.

3. *Temperature of the milk.* Milk that is too cold gradually will clog up the cream outlet, resulting in less and richer cream and a higher-testing skim milk.

4. *Rate of inflow.* As the inflow of milk is regulated by a float or valve, there is little danger of overfeeding the machine. If the supply-tank faucet or valve is not opened wide enough, the machine will be underfed; this means a higher-testing cream, because the usual amount of force is acting on a smaller amount of milk. The skim milk test is not affected.

5. *Richness of the milk.* The richness of the cream obtained is in proportion to the percentage of butterfat in the milk. If the separator is set for a 40 per cent cream when skimming a 6 per cent milk, it will skim approximately a 20 per cent cream with a 3 per cent milk. The skim milk should test the same in either case. Any

factor that affects the herd test, such as fresh cows or the purchase of new cows, will in turn affect the richness of the cream.

6. *Vibration of the bowl.* If the machine does not set level, if the bowl has been handled so roughly that it is out of balance, or if the bearings are worn, the bowl will vibrate and will not skim clean. This means a lower-testing cream and a higher-testing skim milk.

7. *Cleanliness of the bowl.* The machine should be washed each time it is used. Otherwise, milk left in the bowl may sour and clog up the cream opening so that the machine will not skim clean. A dirty machine will not do good work.

8. *Amount of flush water.* Naturally, the amount of water used to flush the bowl will cause the cream test to vary, if the cream spout is allowed to drain into the cream. This is especially noticeable when a small amount of milk is separated. One should use just enough water to cause a watery discharge to start from the cream spout, and then use the same amount from day to day.

An understanding of the above points on the part of separator operators would avoid a good deal of argument over the accuracy of cream tests. It is impossible to make a separator work so that the cream will test exactly the same every day, especially with the hand machine.

Filtration and Clarification. Even though milk is handled under the best of conditions on the farm and in the plant, a certain amount of visible sediment is sure to be present, as well as invisible broken down cells of udder tissue. In order to put out a clean product, the plant must filter or clarify the milk before processing.

FILTRATION. The filter material is generally of canton flannel cloth clamped over a cylindrical perforated metal frame or over a flat, perforated surface. In either case, the filter is enclosed in a sealed jacket or frame so that milk may be pumped through it under pressure. The filter is placed in the line so that preheated milk may be passed through it during the pasteurization process. It is a good idea to have two filters with a bypass in the line, so that one always can be in use while the cloth is being changed in the other one. Filter cloths should be used but once. A filter will strain out visible dirt quite effectively but will not remove leucocytes (udder tissue). These contribute to fine sediment showing in the bottom of a bottle of homogenized milk, and because a very high percentage of market milk is now homogenized, the centrifugal clarifier has come into almost universal use in the milk plant.

CLARIFICATION. Like the separator, the clarifier operates on the principle of centrifugal force throwing the sediment, which is heavier than the milk, to the outside of the bowl where it adheres to the inside of the bowl cover or shell as so-called "slime." Unlike the separator, the clarifier has but one outlet, so that no separation of butterfat takes place. The airtight clarifier, through which the milk enters at the bottom of the bowl near the outer edge of the discs under pressure, is the one in common use. The milk travels upward between the discs and the foreign material is thrown out into the sediment space. Cold milk is most commonly clarified. The operation is carried out in the line between the receiving room and storage tanks or between the storage tanks and the pasteurizer. The clarifier may be placed in the pasteurizing line, between the preheater and heater or between the heater and the holder.

Standardization. The milk plant obviously wishes to sell milk of uniform butterfat content from day to day, and because milk as received from its various farms varies in butterfat content, the various lots must be mixed or standardized. Simply running the milk from

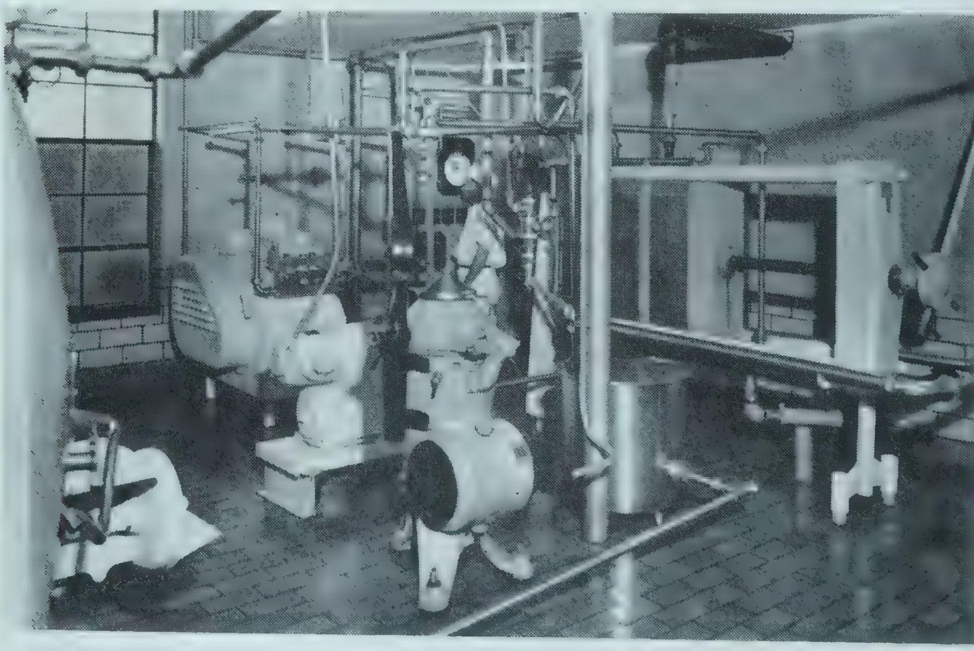


Fig. 85. Shows various dairy processes; end of storage tank where milk is standardized shown at left; clarifier in the central foreground with homogenizer to the rear and a plate pasteurizer to the right of the picture.

a number of producers into a large storage tank is a form of standardizing, and this method is all that is allowed in a few states. More accurate standardization is desirable, however, and known amounts of cream or skim milk can be pumped into a known amount of milk in a tank to raise or lower the fat content to the desired point (3.6 to 3.8 per cent in most market milk). So-called standardizing clarifiers that accomplish clarification and standardization in one operation are now in use. The construction is such that a small amount of cream is bled off from the incoming higher testing milk. This machine cannot be used to standardize milk upward but there is little reason to do this. The machine requires careful operation to produce accurate results, but it does save time as standardization is continuous and there is no chance for contamination.

Homogenization. Milk is far from being a perfect emulsion of butterfat and the balance of the milk constituents (serum). The fat globules vary in size and the average size is said to be about 5 microns. A micron is one twenty-five thousands of an inch. When milk or other fluid dairy products are forced at pressures of 2,000 to 5,000 lb per sq in. through a tiny valve opening, the process is known as homogenization and the machine, really a high-pressure pump, is known as an homogenizer. The valve opening, through which the mixture is literally atomized, is known as the homogenizing valve. The effects of homogenization can be varied by the amount of pressure placed on the homogenizing valve. The result of homogenization is a more perfect emulsion. Fat globules are reduced in size to 2 microns or less, and the general effect is to increase the viscosity and smoothness of the homogenized product. Cream will not rise on homogenized milk, nor will the butterfat churn out of homogenized milk or cream. The homogenizer is used widely in the processing of market milk and evaporated milk, ice cream mix, cream cheese, and cheese spreads. It is probable that 90 per cent or more of bottled market milk is homogenized. The product tastes richer than unhomogenized milk and it is somewhat more easily digested by children, owing to a softening of the curd by the process.

Modern ice cream manufacture would be virtually impossible without the homogenizer. The machine also can make a reconstituted milk by blending butter or butter oil and skim milk or skim-milk powder and water together.

Various tests are used to determine the thoroughness of homogenization. The United States Public Health Service Milk Ordinance and

Code defines homogenized milk as follows: "Homogenized milk is milk which has been treated in such manner as to insure a break-up of the butterfat globules to such an extent that after 48 hours storage no visible cream separation occurs on the milk and the butterfat percentage of the top 100 ml of milk in a quart bottle or proportionate volumes in containers of other sizes, does not differ by more than 10 per cent of itself from the butterfat percentage of the remaining milk as determined after thorough mixing."

Thus, if the top 100 ml of milk carefully poured from a bottle tested 4 per cent butterfat and the balance of the milk, after mixing, tested 3.8 per cent butterfat, the difference (0.2 per cent) is less than 10 per cent of 4 per cent (or 0.4 per cent) and the milk is deemed to be properly homogenized.

For testing other applications of the homogenizer, the product is examined microscopically to determine the uniformity in the size of the fat globules.

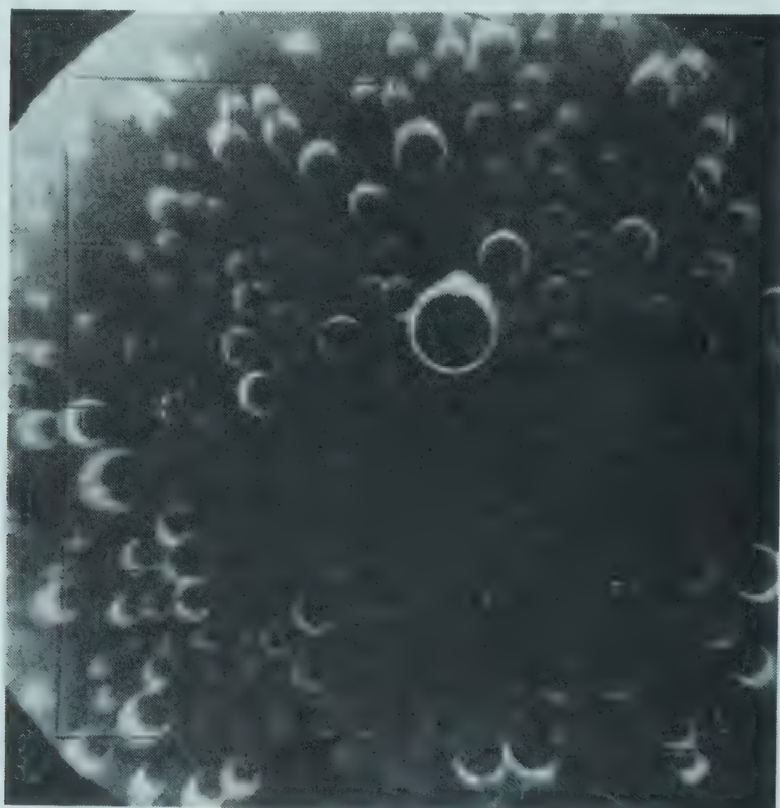


Fig. 86. Fat globules of unhomogenized milk under the microscope at a magnification of about 1,000 times. (A. W. Farrall: Dairy Engineering, John Wiley, 1953.)

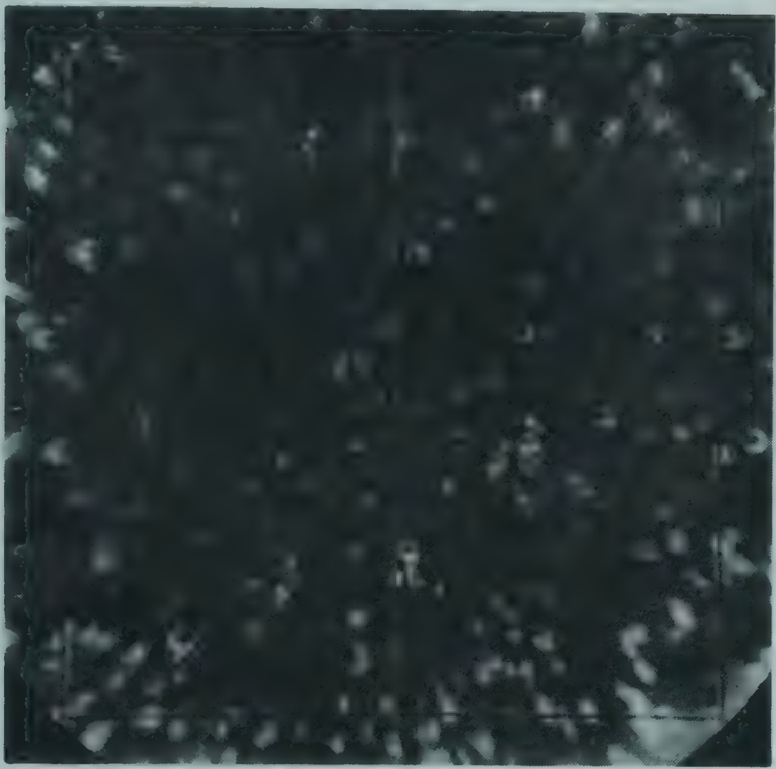


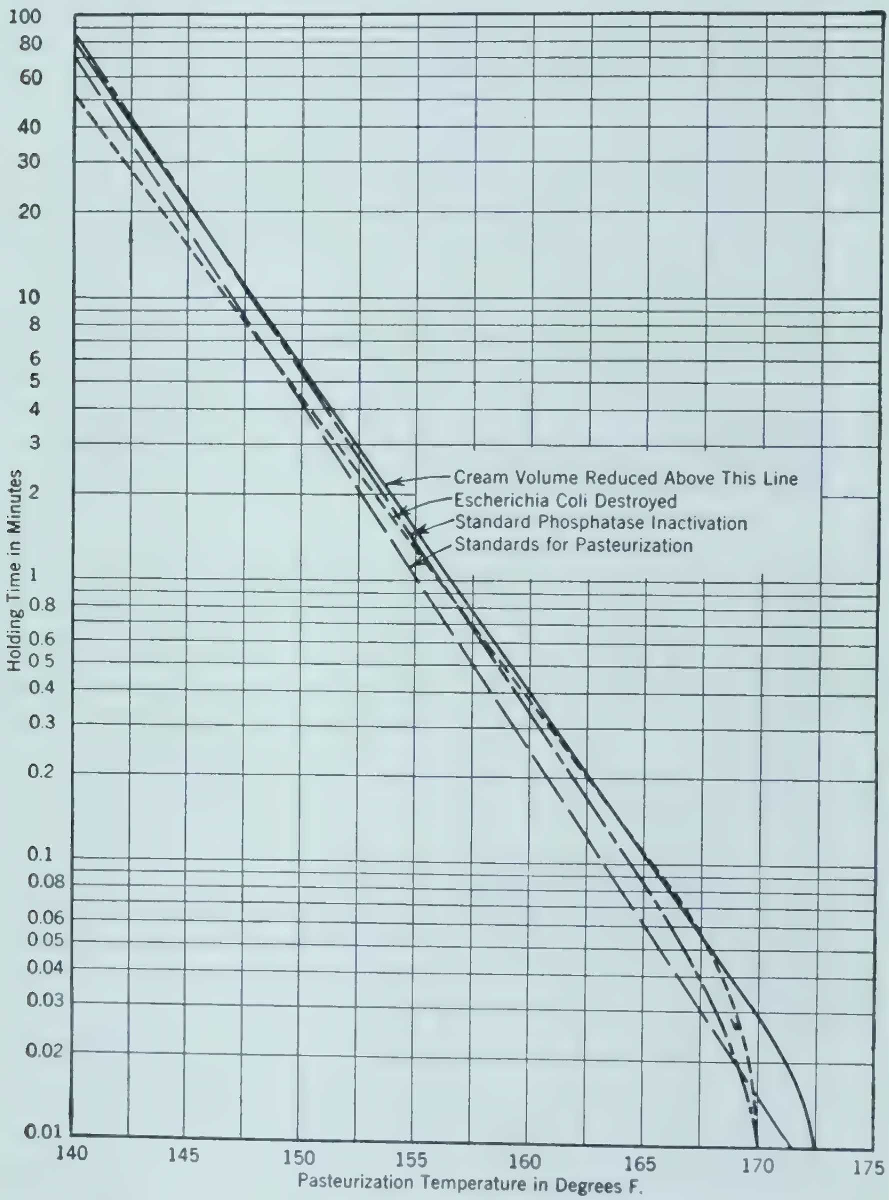
Fig. 87. Fat globules of homogenized milk at a magnification of about 1,000 times. (A. W. Farrall: Dairy Engineering, John Wiley, 1953.)

Pasteurization. Pasteurization derives its names from the famous French scientist, Louis Pasteur, whose experiments about the year 1870 showed that the heating of wine greatly improved its keeping quality. Pasteurization was first used in the dairy business in the 1880's in Germany and Denmark. About 1900 pasteurization was first practiced in the United States. The first compulsory pasteurization law was enacted in 1908 in Chicago. Nearly all city milk supplies and ice cream mix now are pasteurized. Except for some varieties of cheese, pasteurization is practiced in the manufacture of all dairy products. States and cities have regulations governing pasteurization, many of them patterned after the U.S. Public Health Service Milk Ordinance and Code, which defines pasteurization as heating every particle of milk to at least 143° F and holding it at that temperature for 30 minutes or to at least 160° F and holding it at that temperature for at least 15 seconds.

Pasteurization destroys most of the bacteria in milk and all disease producing bacteria, if any be present. The keeping quality of the product also is greatly enhanced.

There are two basic types of pasteurization in use today, the holding process and the short-time high-temperature process.

HOLDING PROCESS. This is a batch process whereby the product is heated to 143° F for 30 minutes. The equipment is of three basic types, vertical or horizontal coil vat, spray vat, and vertical jacketed tank.



[*From Bul. 254, New York (Geneva) Agr. Exp. Sta.*]

Fig. 88. Composite of the relationship existing between creaming, phosphatase test, bacterial destruction, and an improved standard for pasteurization.

In the coil vat, hot water is circulated through rotating coils, thereby accomplishing agitation and heating. The spray vat is a jacketed vat with a spray pipe running around near the top. Hot water is sprayed down the sides of the vat, and paddles that move back and forth keep the product agitated. In the jacketed tank, hot water is circulated through the jacket and various types of agitators are used for stirring the product.

Since cooling the pasteurized product to 50° F or below is really a part of the process, some of these holder pasteurizers are equipped for the substitution of ice water for hot water, so that the product may be cooled.

Sometimes holders are used simply to hold the milk at the required temperature, after the product has been heated outside the holder with a so-called preheater. Preheaters are of four general types: box tube, internal tube, shell and tube, and plate. In the box tube type, the product is circulated through sanitary pipe immersed in an enclosed "box" of circulating hot water. In the internal tubular type, the product circulates through an inner pipe surrounded by circulating hot water in a space between the inner and outer pipes. The shell and tube heater works on the same principle. The milk passes through a series of pipes enclosed in an outer shell like boiler tubes, and heating is accomplished by circulating hot water or low-pressure steam through the shell. The plate heater has come into extensive use. A series of stainless steel gasketed plates are held together in a press so that circulating water on the one side heats the product on the other side.

The holder process is now used for the most part in small milk plants and in various manufacturing operations.

SHORT TIME HIGH TEMPERATURE PASTEURIZATION. As the name implies, the product is heated higher and held for a shorter time than in the holding process. Definition has already been given. There is some trend toward the use of temperatures up to 260° F with little or no holding time at all. This method is called "flash" pasteurization.

This system has some advantages over the holding process.

1. Less floor space is required.

2. The original cost of equipment is lower, although this saving may be partially offset by use of better heaters and controllers.

3. The capacity of the equipment is more easily expanded.

4. Labor can be better utilized because bottling can start almost as soon as pasteurization begins.

5. Equipment is more easily cleaned and sanitized by C.I.P. (cleaning in place) procedures.
6. Thermophilic (heat-loving) bacteria are less troublesome.

Some disadvantages of this method are:

1. Bacterial reduction is sometimes not as great, probably because of a greater survival of thermoduric bacteria. Control of thermoduric bacteria in raw milk supplies thus becomes more important.
2. Where plate units are used, the gaskets require special care in cleaning.
3. Usually a sweet-water cooling system is an integral part of the HTST (high-temperature short-time) unit. This may involve the need for expanded sweet-water capacity in the plant, or installation of a complete sweet-water system.

In HTST pasteurization, raw milk is fed into a constant level supply tank from which it is pulled through a regenerator section by a positive pump with a carefully adjusted speed. The cold raw milk is warmed by the hot pasteurized milk flowing in reverse direction across the opposite side of the plates in the regenerator section. The warm raw milk then goes through the pump which forces it through the remainder of the unit. First it goes from the pump through a filter or clarifier and homogenizer if one is used, and then into the heater section. Here hot water flowing across the opposite side of the plates heats the raw milk to exactly the holding temperature (usually 161° or 162° F). The milk then emerges into the holding tube. This tube is of such diameter as to give a flow velocity of 1 to 2 ft per second and is carefully adjusted as to length so that the milk will take exactly 15 or 16 seconds to travel through it. The holding tube ends at the flow-diversion valve. This valve is temperature activated. If the milk is at the set temperature at this point, the valve lets it pass to the regenerator section. If the milk at the flow-diversion valve is not at the proper temperature (161° or 162° F), the valve automatically diverts it back to the raw supply tank for re-treatment. If the milk is permitted to proceed into the regenerator section, it gives up some of its heat to the cold raw milk coming through this unit and is itself cooled by the incoming cold milk.

Regeneration always saves heat and refrigeration with no loss except by radiation (less than 1 per cent). The Btu balance between heat given up by the hot milk and that picked up by the cold is equal. In units having 80 per cent regeneration (and 80 per cent is quite common with today's units) the heating and cooling loads are as follows:

Starting with milk at 40° F to be pasteurized at 161° F and cooled to 40° F with 80 per cent regeneration 0.80 × (161°–40° F) + 40°, the milk is raised from 40° to 136.8° F in the regenerator. Therefore, the actual additional heat needed to raise the temperature of the milk to 161° F is 24.2° (161°–136.8° F). Cooling from 161° to 64.2° F is accomplished on the outlet side of the regenerator, so the actual refrigeration needed is enough to cool the milk from 64.2° to 40° F or 24.2° F. With vat pasteurization (no regeneration), heat is required for the full job of raising milk from 40° to 145° F. It then flows over the cooler and to the surge tank which supplies the fillers.

A number of controls usually are arranged on a panel close to the unit. A temperature-sensitive recorder-controller activates the flow-diversion valve, through a solenoid valve, by means of compressed air. The device also acts on an air-operated steam diaphragm valve, which regulates the amount of steam introduced into the hot-water heating medium. Finally, the cooling is controlled by a thermometer installed at the cooling section outlet which activates a solenoid valve and a throttle valve in the sweet-water line. These controls make the operation of the HTST unit automatic, once it is properly started and adjusted.

Public health authorities check the operation of all HTST pasteurizers when they are installed and, as a rule, periodically thereafter.

More recently vacuum equipment has been developed for installation in the short-time high-temperature line of product flow. The object is the removal of volatile off-odors from milk, such as wild onion for example. This equipment appears to be giving beneficial results and is used quite extensively in areas where these flavors are bothersome.

Vitamin Fortification of Dairy Products. Most homogenized milk contains added vitamin D at the rate of 400 units per qt. Several companies supply vitamin D in concentrate form, preferably in a milk base. The job of handling the concentrate should be vested in the laboratory, because (1) it is important to avoid contamination of the product after a package is opened, and (2) it is important to add the right amount of concentrate to a given amount of milk. By knowing the amount of milk in a storage tank and the strength of the concentrate in vitamin D units, the amount necessary can be measured out, diluted with a small amount of milk and added to the tank of milk. The milk must be thoroughly agitated before processing and

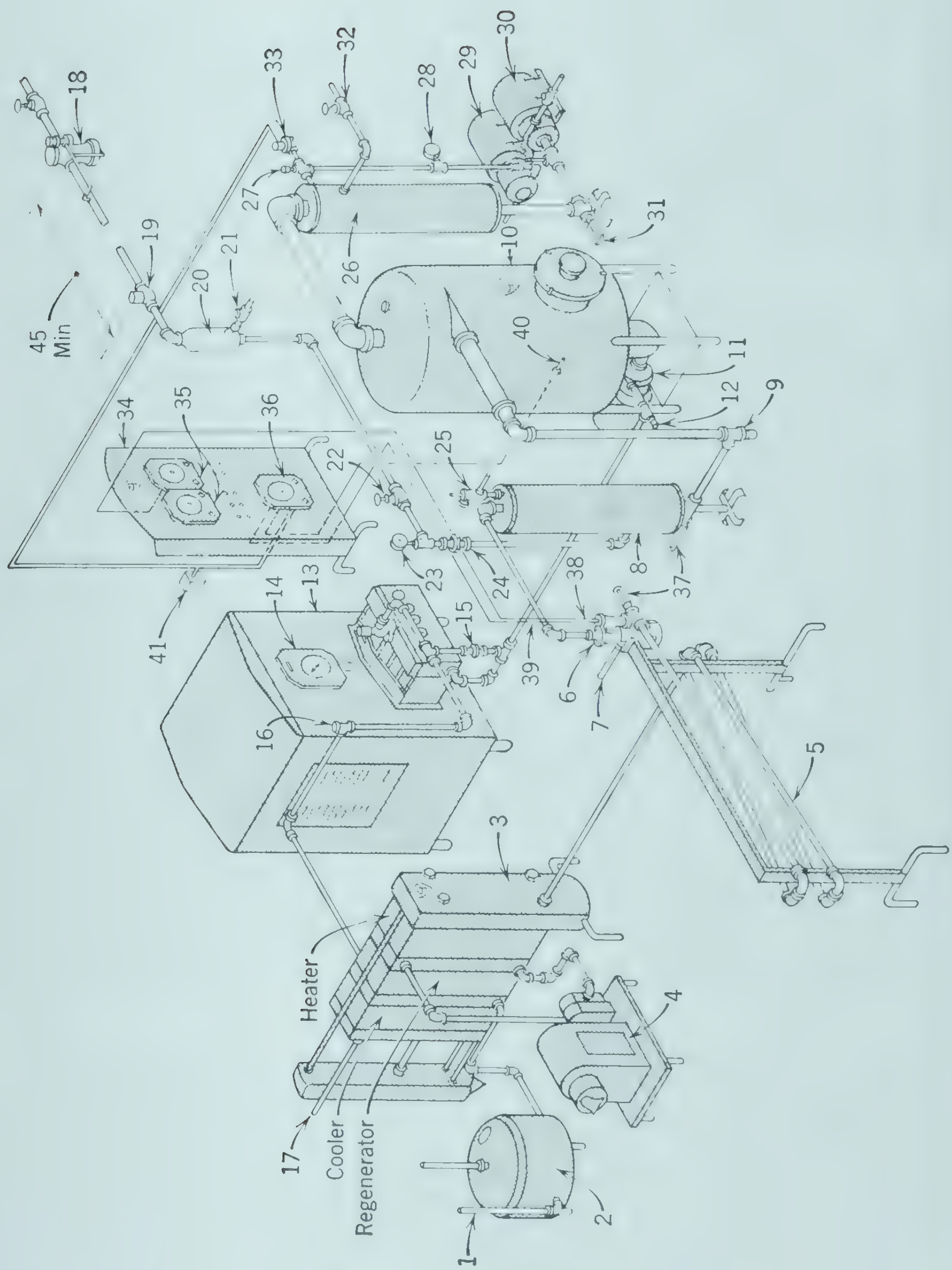


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Fig. 89. Vacuum heat-treating process designed for flavor improvement. (Courtesy Creamery Package Mfg. Co.)

1–Raw product in
2–Raw product constant level tank (balance tank)
3–Plate heat exchanger
4–Timing pump
5–Holder tube
6–Flow diversion valve
7–Diverted flow line
8–Steam infuser
9–Pressure control–check valve
10–Vaporizing cylinder
11–Product removal pump
12–60 RT compression–check valve
13–Homogenizer
14–Homogenizer pressure gage
15–Check valve
16–Vacuum breaker
17–Cold pasteurized product out
18–Steam pressure reducing valve
19–Solenoid valve
20–Steam purifier
21–Steam trap
22–Steam flow control valve
23–Pressure gage
24–Sanitary check valve
25–Air control valve–vacuum breaker (air-filter incorporated)
26–Condenser
27–Snifter valve
28–Vacuum gage
29–Vacuum pump
30–Water pump
31–Thermometer
32–Condensing water supply
33–Vacuum regulator
34–Panel board
35–Recording controller and safety thermal limit recorder
36–Ratio controller–recorder
37–Sanitary indicating thermometer
38–Safety thermal limit recorder (HTST–flow diversion valve) bulb
39–Ratio controller bulb
40–Ratio controller bulb
41–Safety pressure switch

Fig. 90. Results of Vitamin D assay; joints diseased with rickets shown at top; healing showing the feeding of vitamin D milk at bottom. (Courtesy Dr. Lloyd C. Miller, U.S. Pharmacopoeia.)

care must be taken that there is no nonvitamized milk in the system, that is, on coolers or in pipelines, so that the vitamin D milk becomes diluted.

Vitamin D milk must be labeled as such, with a statement to the effect that it contains 400 U.S.P. units per quart. Most health departments require one or more assays per year to see if the required vitamin D unitage is present. There are a number of college and private laboratories equipped to do this work. It involves rat feeding over a period of several weeks, the killing of the rats and an examination of their bones to determine if calcium development has been sufficient due to the added vitamin D. To a more limited extent, other vitamins are being added to milk or skim milk to make a so-called multivitamin product.

Equipment Sanitizing. The daily cleaning and sterilizing of equipment after each use is a major operation and may account for 15 to

20 per cent of the total man-hours required to operate the plant. The details of this operation would require an entire manual or book, so that only a general idea of what is required will be mentioned here.

In general, cold milk leaves a light deposit of milk solids on equipment so it can be cleaned easily. Hot milk deposits cooked-on solids that require more effort to remove.

Two types of cleaning are in vogue; manual and cleaning-in-place (C.I.P.). Manual cleaning consists of warm water rinsing, hand-brushing with a cleaning solution, clear hot water rinsing, followed by sterilization with very hot water or a chemical, generally a calcium or sodium hypochlorite. Power driven brushes are used to some extent, especially in cleaning sanitary pipelines. These lines are of stainless steel, with pyrex glass tubing coming into use to some extent.

The cleaner used and the strength of its solution depends upon the hardness of the water supply and the type of soil to be removed. Once this cleaner is decided upon, the amount should be measured out each time, both for best results and for the economical use of cleaner.

In recent years it has been found that a good job of in-place cleaning can be done, thereby saving on the labor needed and reducing the wear on equipment. Briefly, in-place cleaning is the cleaning of sanitary pipelines while they are in position, without disassembling them. Generally, the procedure is to pump rinse water through them to remove the free soil until it runs clear. Then either an acid cleaning solution and an alkaline cleaning solution or an alkaline cleaning solution by itself is pumped through them (with a rinse between the acid and alkaline cleaning solutions if both are used). Rinse water is pumped through the pipes until they are free of cleaning solution, and, finally, they are "sterilized" by pumping through either hot water or a solution of sodium hypochlorite. All lateral connections are "broken," connections in the lines are "capped," and, after the cleaning solution (or solutions) have been circulated, lines are "decapped" and manually scrubbed, after which the caps are replaced and the procedure completed.

Tanks may be cleaned by rinsing and by spraying with cleaning solution (using varying types of nozzles), followed by hot water rinsing. Chemical spraying is done to sterilize tanks using a 200 to 250 parts per million of chlorine solution.

Waste Disposal. Waste disposal is a real problem in country plants where streams are not available or where polluting the streams with dairy waste kills fish or constitutes an odor nuisance. The *Manual*

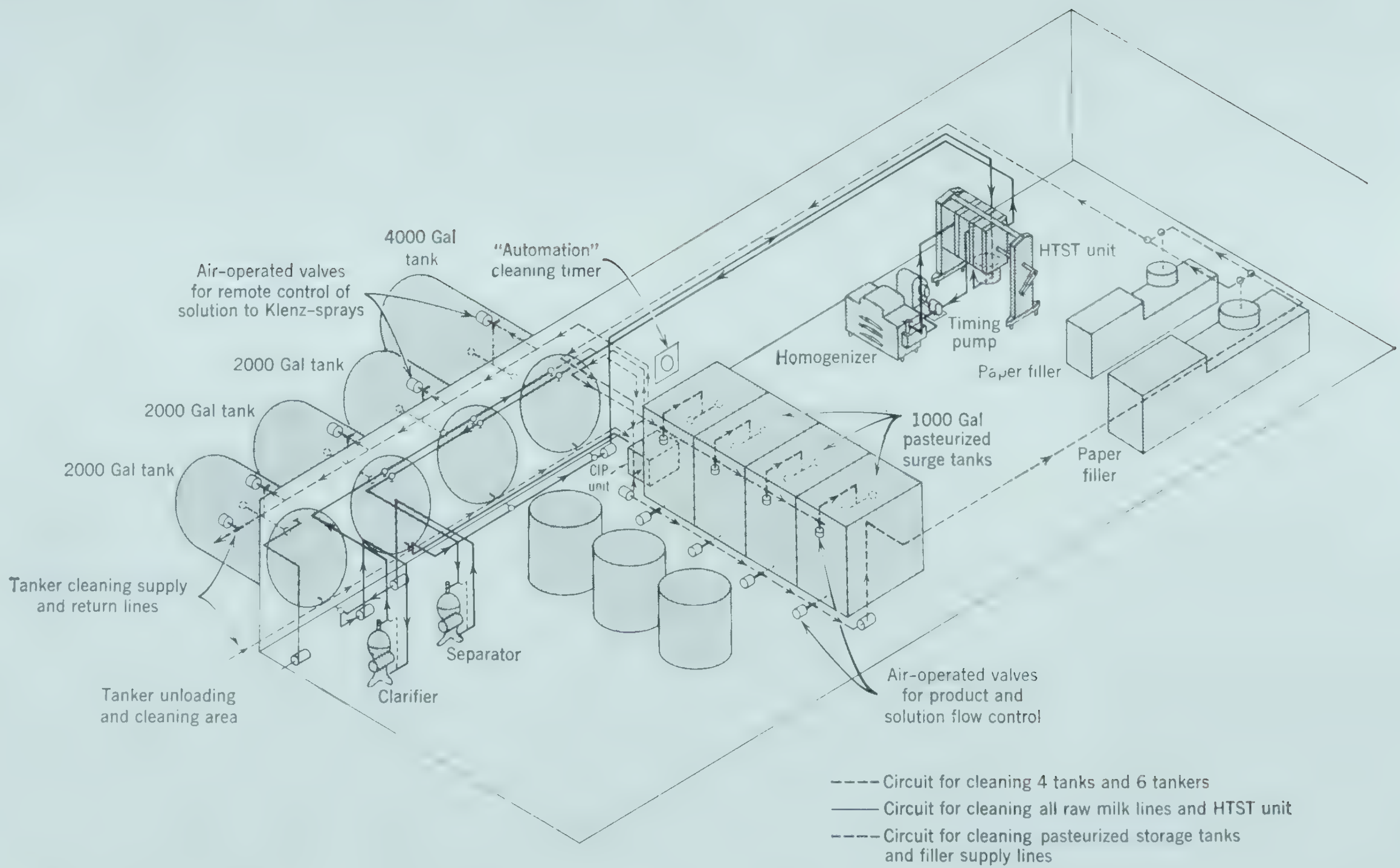

Fig. 91. Typical arrangement of equipment and sanitary piping to permit recirculation and spray cleaning by CIP procedures from a single, centrally located recirculating unit. (Courtesy Klenzade Products, Inc.)

*for Milk Plant Operators** lists 43 suggestions for preventing waste. This approach is sensible, because care in such things as draining and saving the product from equipment, preventing the product from freezing on coolers, and preventing overfilling of vats or tanks saves the plant money in product and in the cost of waste disposal plants.

QUESTIONS

1. What are the two general methods in use for separating cream from milk?
2. What are the steps in the use of the shallow pan method of separation?
3. How does the deep-setting method of separation operate?
4. Describe the principle of centrifugal separation.
5. How long have separators been in commercial use?
6. What are the advantages of the separator method?
7. What is the air-tight separator and what are its advantages?
8. What is the cold milk separator and what is its particular application?
9. List the factors involved in the care and operation of the separator.
10. What is the cream or skim milk screw and how does it regulate the richness of cream?
11. Why is cream test lower if the machine is operated at too low a speed?
12. Why would an underfed machine result in higher testing cream?
13. Why would a high butterfat content milk result in higher testing cream than low butterfat content milk, assuming the position of the cream screw remains the same?
14. Why is the separator bowl flushed with water at the end of the run?
15. What is filtration and how is it generally done?
16. What are the major differences between the separator and clarifier?
17. Why has the clarifier largely replaced the filter in the milk plant?
18. How can milk be standardized in a continuous operation?
19. What is meant by homogenization?
20. What is a micron and how many microns in diameter are the fat globules in properly homogenized milk?
21. What are other uses of the homogenizer in addition to homogenizing milk?
22. Why is such a high percentage of bottled market milk homogenized?
23. How does one determine the thoroughness of homogenization?
24. Define the two methods of pasteurizing milk.
25. What is the derivation of the term "pasteurization"?
26. What are the two general methods of operating the holder process?
27. What are the advantages and disadvantages of short-time high-temperature pasteurization?

* Published by the Milk Industry Foundation, Washington, D.C., 1957.

28. What is a flow-diversion valve?
29. What is meant by regeneration and how does it operate?
30. What are the major controls used on pasteurization equipment?
31. What is the object of using vacuum equipment in connection with the pasteurizing process?
32. What is the usual rate of vitamin D addition to milk?
33. What are some of the precautions that must be taken in the plant in the use of vitamin D concentrate?
34. What is meant by C.I.P. cleaning? Outline the procedure.
35. How is equipment commonly sterilized?
36. Why is waste disposal such a problem for country plants and what precautions can be taken to reduce the problem to the minimum?

PROBLEMS

1. When 10,000 lb of 3.5 per cent milk are separated, 9,000 lb of skim milk, testing 0.05 per cent, result. Find the amount and test of the cream that was obtained. *Ans.* 1,000 lb of 34.55 per cent

2. How much butterfat is lost in the skim milk when from 500 lb of 3 per cent milk, 50 lb of 28 per cent cream is skimmed? What would the skim milk test? *Ans.* 1 lb butterfat lost in skim milk, 0.22 per cent

3. The cream screw of a separator is set for a 30 per cent cream. How many pounds of 4 per cent milk must be separated to get 100 lb of 30 per cent cream, if the skim milk tests 0? *Ans.* 750 lb milk

4. A hand-separator creamery received in one day 25,000 lb of cream from 5 stations, each shipping in 5,000 lb of 30 per cent cream, according to their test. When the cream was tested at the creamery, it was found that 3 stations were 2 per cent short and 2 stations 3 per cent short of the total amount of butterfat they were supposed to have delivered. (*a*) How many pounds of butterfat are lost? (*b*) What is the average test of the cream at the creamery?
Ans. (*a*) 180 lb butterfat lost, (*b*) 29.28 per cent test at creamery

5. A man produces 120,000 lb of 4 per cent milk in one year; 28,000 lb of cream is raised from this milk by the deep-setting system, and averages a test of 16 per cent. Find the test and loss of butterfat in the skim milk. He buys a 900 lb per-hour separator for $110.00, and from the same milk takes 13,600 lb of 35 per cent cream. Find the test and loss of butterfat in the skim milk. With butterfat at 38 cents per lb, how many days must the separator be used before it will save enough to pay for itself? At 50 cents per cwt, what would the extra skim milk be worth when the separator was used?
Ans. 377.3 days, $72.00 more for skim milk

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CHAPTER 17

Market Milk from Farm to Consumer

Retailing from the Farm. When the farmer retails his own milk, he usually gets greater returns than when the milk is sold in any other way. The method, however, has many disadvantages. Some of these are: (1) it is a tedious job; (2) it is hard to get qualified men to deliver milk; (3) much of the time required is needed for other farm work; (4) there are losses due to bad bills; (5) a considerable quantity of special equipment is needed; it is generally required that the milk be pasteurized; (6) the public is not sufficiently safeguarded as to quality; (7) great duplication of routes is likely to occur; (8) there is a large bottle loss; (9) the problem of maintaining a never-failing supply is a serious one. Of course, only those farmers living relatively near the market can sell their milk by this method.

Selling Wholesale to City Dealer. This method of sale involves the least work on the part of the farmer. The milk simply is put into cans of various sizes, such as 8, 10, 20 and 40 qt, and, after cooling, is hauled to the shipping station or, as explained in the previous chapter, the bulk tank system is used. When milk is sold by this method, the transportation problem is a big one. With the great growth of the cities, milk frequently is shipped a distance of 200 to 400 miles. Most of the milk is transported by truck but some, from more distant points, is transported to market in milk cars which are attached to regular trains, or, in the case of a large market, are run as a special train. There are two types of milk cars. One, the common insulated car

Fig. 92. Can pickup of milk from the farm.

which carries cans of milk, and the other the so-called tank car which transports the milk in large tanks. Different methods of refrigeration are used in the different cars, but in all cases the milk is transported at very low temperatures. To supply very large cities, the milk from distant points is picked up at the farm and taken to a receiving plant where it is weighed, sampled, cooled, and assembled in storage tanks for shipment by truck or train to the city plant.

One of the first considerations, when milk is sold at wholesale, is the basis of payment. The old method was to sell by the quart, gallon, or can, regardless of the test of the milk. Milk now is bought by the hundredweight and generally a premium is paid for butterfat content. Sometimes a premium for cleanliness and low bacterial count is paid. This is the only fair way to deal in milk. Cans be-

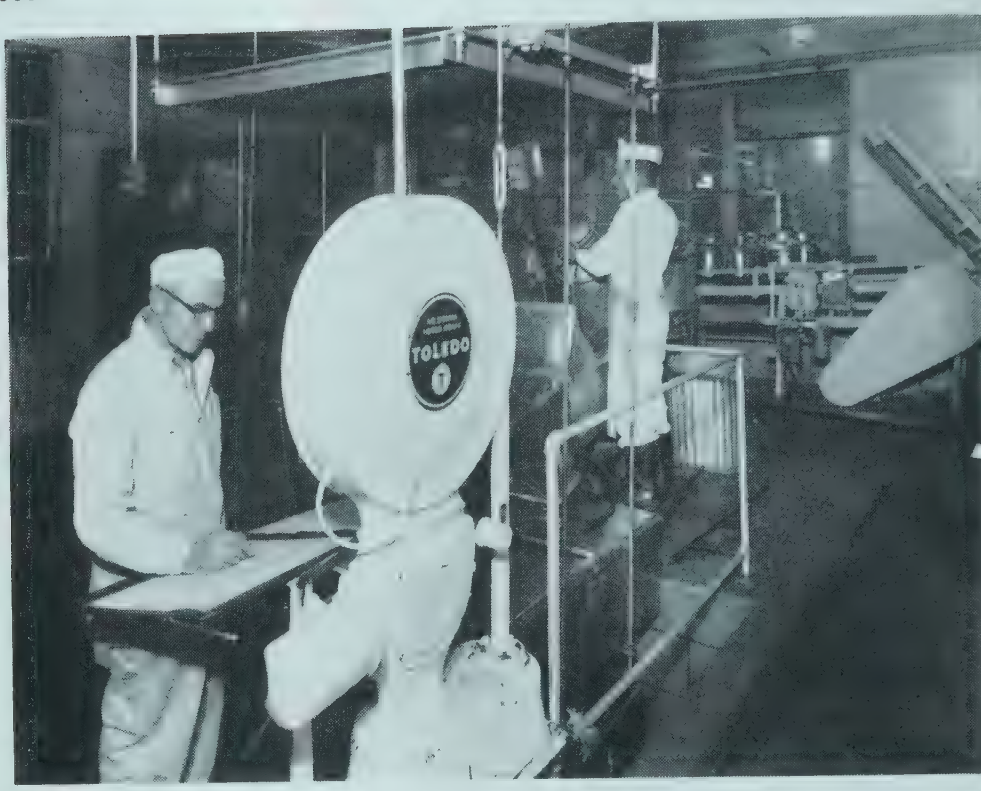

Fig. 93. Receiving milk in cans.

come battered or are not filled, and consequently do not hold their stated volume. Milk with 5 per cent butterfat in it is worth more for any purpose than milk with a 3.5 per cent butterfat content; and clean, good-flavored milk is much better than a dirty, poor-flavored product.

The consumer demand for fluid milk varies from day to day and month to month. To take care of its peak demand, a company must buy more milk than it can sell as fluid milk. Coupled with this is the fact that more cows freshen in the winter and spring and as they go out to lush pasture, a tremendous increase in production occurs in May and June. These facts make for what is known as surplus milk or that over and above what the dealer can sell as fluid milk. This surplus milk must be made into manufactured dairy products in competition with the great manufacturing milk producing areas that are more remote from the large cities. The dealer can, therefore, pay less for this milk than for that going into the bottle. This brings about what is known as an average or blended price that could vary considerably. This, coupled with the fact that problems arose

as large companies tried to deal individually with hundreds of producers, led to the formation of cooperative milk producer associations which now have become established all over the country around large milk markets. The associations are federated into one large body, known as the National Milk Producers' Association, with offices in Washington, D.C. These cooperative associations handling fluid milk are commonly divided into three types: (1) bargaining associations, which do not actually handle any of the milk but find the market and arrange the terms of sale; (2) operating or marketing associations, which own and operate facilities for processing surplus milk or for assembling milk for fluid uses; and (3) distributing associations, which own and operate facilities for pasteurizing, bottling, and selling milk, cream, and other dairy products at retail or wholesale or both.

Although from the producers' standpoint these bargaining cooperatives were a step in the right direction, producers had to be sold on the idea of joining an association and, of course, not all would join, because there were always some small to medium-sized companies ready to deal with these producers at a price in excess of the blended price paid association members. These dealers could afford to pay

Fig. 94. Bulk tank pickup of milk from the farm. (Courtesy The Heil Co.)

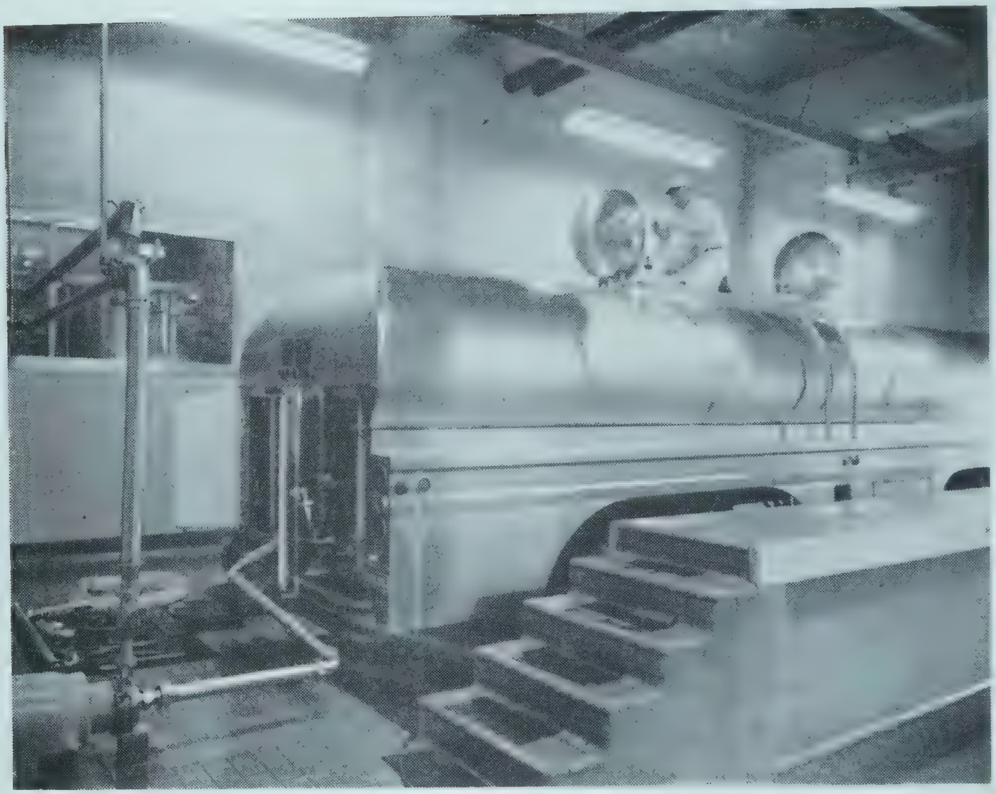

Fig. 95. A modern tank truck for hauling milk from country receiving station to the city; unloading at city plant.

producers higher prices and to sell at retail at a price below the dealer buying through the association, because they bought little or no surplus milk. All of this chaos led to the creation of milk control boards by various state legislatures, the first being in New York State in 1933. These boards had difficulty in enforcing their orders because so much milk crossed state lines on its way to market. This fact led to Congress' passing the Agricultural Marketing Acts of 1937 and 1938, whereby federal orders have become established in all major markets establishing blended prices that must be paid to producers in each market.

These orders were set up, however, only after extensive public procedure. In the case of federal orders this included a preliminary study, open hearings, a review by the Department of Agriculture, a formal issuance of the order by the Secretary of Agriculture, and a vote on the order by the farmers affected. The Government does not initiate federal orders for milk markets. The machinery starts

when some group of producers, almost always a cooperative, proposes a federal order.

The proposed order goes to public hearings. The Department of Agriculture then spells out an order conforming to the apparent consensus of the hearings.

This order must conform to certain specifications laid down by Congress, however. For instance, it must "insure a sufficient quantity of pure and wholesome milk," but, also, must "be in the public interest, treat all farmers equally, and not exclude any producer otherwise eligible."

The proposed order then goes to a vote of all the dairy farmers who supply the market. A two-thirds favorable vote is required. Cooperatives may vote their entire membership as a block. If the vote is favorable, the Secretary of Agriculture announces that the order is in effect. Milk-handlers are the only persons regulated under federal orders.

Today's federal orders do not fix prices, but fix merely the factors which shall be taken into account, from month to month, in their determination. Thus every month the Milk Administrator for each federal-order market officially publishes the blended prices to be paid producers for the market. But he does not pick these prices out of a table. He follows the formula for that month. The formula is the same each month, but there are changing factors which are applied to it. All are set out in the order. Any interested person can make the same calculations.

The formulas, which vary for different markets are quite complicated. It will suffice to say that milk is bought in different classifications depending on its use by the dealer. Prices for each classification are established, and the blended price is dependent on the amount of milk used in each classification. Although the road is not always smooth, this system of buying milk has stood the test for over 20 years.

One of the problems that constantly is arising both in the mind of the producer and the consumer is, "Why is there such a large spread between the price paid to the producer and the price paid by the consumer?" Many studies have been made to answer this question. For 1954, for instance, the Milk Industry Foundation's survey results were based on reports from 401 milk-handling firms in 46 states and the District of Columbia. The results showed that for each dollar which these companies averaged in "net trade sales" from customers, the companies in turn paid out:

Cents	
47.15	To the farmer for milk
8.95	For other raw materials going into the products
0.85	For "purchased transportation" to pasteurizing-bottling plants
22.16	For wages, commissions and salaries
5.52	For containers
5.53	For plant, delivery, and office supplies
7.56	For taxes and licenses, insurance, advertising, depreciation and all other expenses
97.72	For all costs

These expenses left the companies a net operating profit of two and one-quarter cents on each dollar of sales. This profit is slightly more than a half-cent per quart. Because this was an average, some companies must have made more, some less. The report showed that on the average (in cents per quart):

The customer paid	22.94 cents
The farmer received	10.82 cents
The handler had other costs of	11.60 cents
The handler had left for himself	0.52 cents

Thus, on an average, these companies had to sell almost 200,000 quarts of milk to make a profit of $1,000—or almost 200,000,000 quarts to make a million dollars of profit. This clearly shows that a company must have a large volume to make the business of real interest.

Handling the Milk at the City Plant. The modern city milk plant is a model of cleanliness, and contains much expensive machinery; the plant and equipment, therefore, represent a large investment for the dealer. Upon arrival at the plant, the milk is usually weighed and examined for flavor and odor and sampled for butterfat. Frequently, sediment tests, methylene-blue reduction tests, bacterial counts, and other quality control tests are made. After weighing, the milk is pumped to large storage vats of 2,000 to 5,000-gal capacity. In some cases it may be clarified and cooled on the way from the receiving room to the storage tanks. Milk arriving in tank trucks from country receiving stations or farm bulk cooling tanks is weighed as a check on country weights or measurements. If the milk is not cooled to 40° F or below before it enters the storage tank, it is cooled in the tank and held until ready for processing. The milk is first stand-

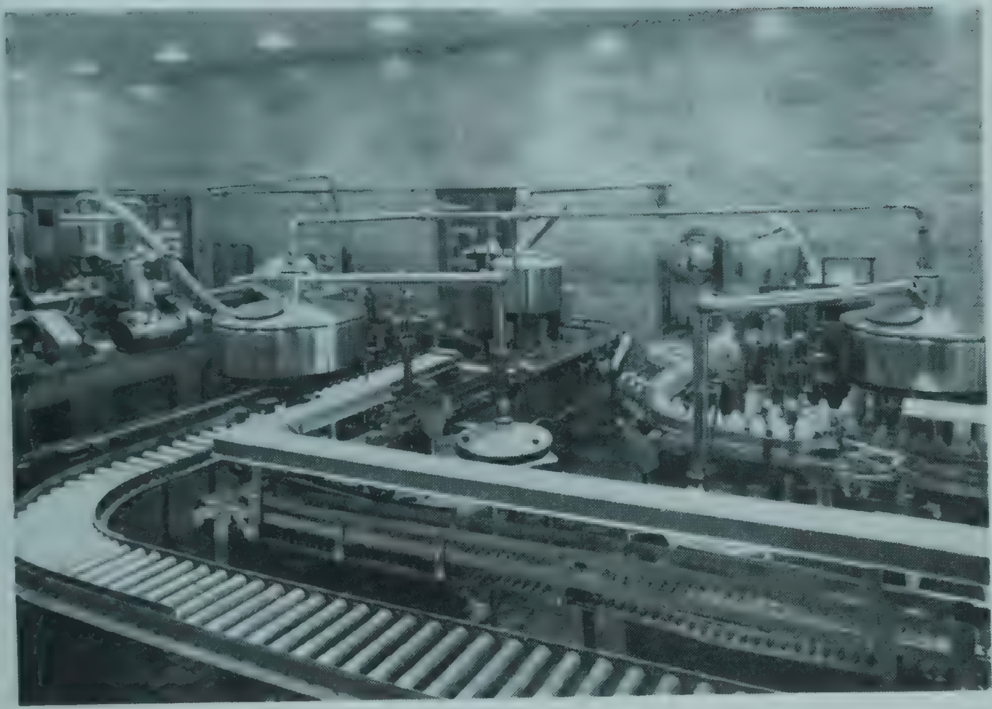

Fig. 96. Glass bottling operation. (Courtesy Hiland Dairy Co., Springfield, Mo.)

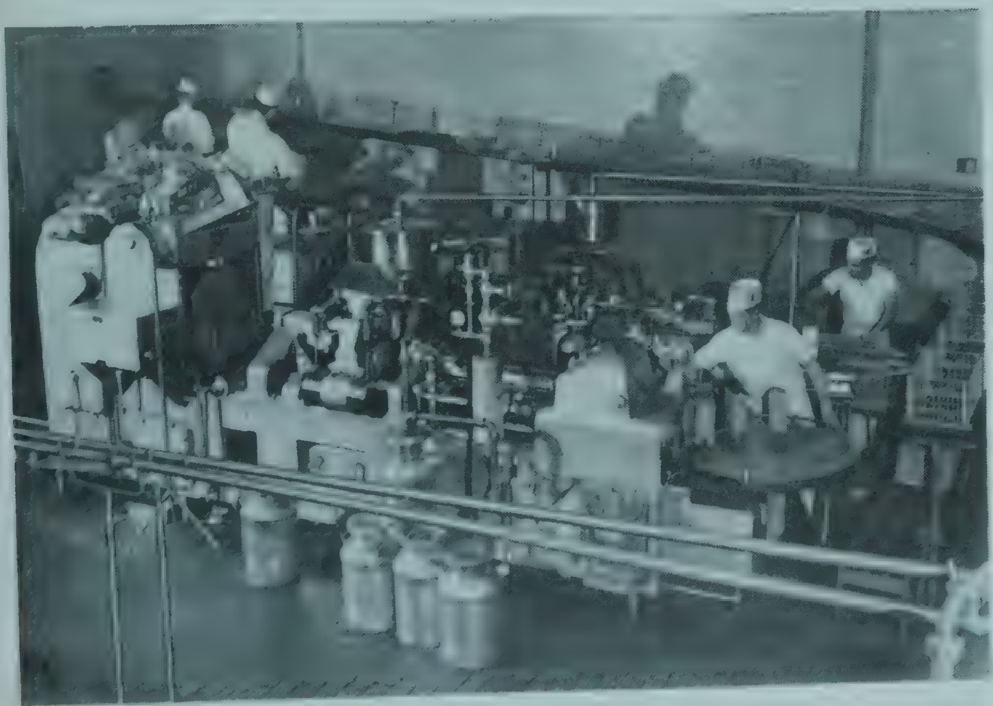

Fig. 97. Paper bottling operation.

ardized to the desired butterfat content, following which it is clarified. Most of it is homogenized, and all of it is pasteurized, cooled, and bottled for the retail and store trade or canned for wholesale outlets, such as eating establishments and bakeries. The product is kept in a refrigerated room until loaded on to delivery trucks. The paper single service container has replaced to a considerable extent the glass bottle, especially for the store trade, and more and more milk is being sold through the store. The retail route now delivering milk on an every-other-day basis in most markets is becoming a thing of the past in very large urban centers.

In addition to regular homogenized milk, most plants process other grades or types, such as regular cream line, cream line and homogenized vitamin D milk, multi-vitamin milk, and a grade higher in fat content in some instances. Added to this list of milks, the plant processes skim milk with or without added vitamins, two to three grades of cream, one or two types of buttermilk, cultured sour cream, one or two types of cottage cheese, chocolate milk or drink or both, and some bottled orange juice or drink. When one considers that

Fig. 98. Refrigerated milk storage room. (Courtesy Hiland Dairy Co., Springfield, Mo.)

Fig. 99. Refrigerated wholesale milk delivery truck.

each of these items goes into quart, one-half pint and sometimes pint containers, not to mention wholesale containers, he gets an idea of the job of planning and accounting for the day's operation.

Side jobs in the milk plant involve the operation of the can washer and, where the glass bottle is in use, the bottle washer. A number of plants are using paper exclusively for the retail package, which simplifies the plant operation and makes for a neater, dryer operation. The cleaning of equipment each day will account for 15 to 20 per cent of the plant labor force requirement.

Milk delivery equipment has changed almost entirely from the horse-drawn wagon to the motor truck. The latest development is the mechanically refrigerated truck body, now used quite extensively in wholesale delivery and coming into use on retail trucks.

Sanitary Regulations. All major cities and states have sanitary regulations for the production, transportation, processing, and delivery of milk. Unfortunately these are not all uniform, and where milk from a certain area goes to more than one city market, duplication and confusion in inspection results. The Model Milk Ordinance and Code fostered by the U.S. Public Health Service is the most complete set of rules, and it has been adopted by a large number of cities throughout the country. For their own protection and constant improvement of quality, the milk companies employ field men to work among their producers, both to help them with quality problems and to maintain good producer-company relations. The results of

tests of samples taken as the milk is received are given to the field man, who uses them as a basis of his quality work in the field.

QUESTIONS

1. What is the advantage and what are the disadvantages of retailing milk from the farm?
2. How does milk get from the farm to the market when sold wholesale to the city dealer?
3. On what basis does the city dealer now purchase milk and why?
4. What is meant by surplus milk and what are the causes?
5. What is meant by a "blended" price?
6. What are the various types of cooperative associations handling fluid milk?
7. What were the underlying reasons for the establishment of state milk control boards?
8. What is meant by a Federal Marketing Order?
9. What are the steps that are taken in the establishment of a Federal Marketing Order?
10. What is the function of the milk administrator in the operation of a Federal Marketing Order?
11. What is the answer to the question as to why there is such a large spread between the price paid to the producer and the price paid by the consumer?
12. What platform tests does milk undergo upon arrival at the city plant?
13. List step by step the process that milk passes through from the time it arrives at the plant until it is placed in the bottle.
14. Why do you suppose the trend is toward purchasing milk at the store?
15. Why is the paper bottle replacing the glass bottle as a container for milk?
16. List the products commonly processed by the milk plant.
17. State a figure that represents the percentage of total plant labor used for cleaning equipment.
18. Why is the mechanically refrigerated milk truck body coming into such common use?
19. What are the functions of the company field man?
20. Why are state and federal regulatory agencies so interested in the production and handling of milk?

PROBLEMS

1. If a man were paid at the rate of $1.10 per cwt for 3 per cent milk and 3 cents per cwt additional for each tenth of a per cent of butterfat

above 3 per cent, how much would he lose or gain in 365 days if he sold an average of three 40-qt cans per day and payment was made according to a 4 per cent test, when payment should have been made on a 3.5 per cent test? *Ans.* $141.25 gain to farmer

2. A man sells 500 qt of cream a week at 50 cents per qt. The cream is supposed to test 25 per cent, but instead tests 28 per cent. How much money does the man give away in a week? A quart of cream equals 2.1 lb. How could he have avoided this loss? *Ans.* $30.00

3. A man keeps 10 cows, each giving an average of 800 lb of milk each month. The milk tests an average of 4.5 per cent. He sells the milk on a butterfat basis and receives 72 cents a lb for 6 months and 68 cents a lb for 6 months. How much more would the milk have brought for the year if it had been sold for 7 cents a qt for 3 months and 8 cents for 9 months? *Ans.* $436.46

4. Two dealers, A and B, each have a surplus in July of 44 per cent. The milk price f.o.b. Boston is $4.30 per cwt for both dealers. A gets $3.56 per cwt out of his surplus and B $4.22. What is the difference in returns to two farmers each selling 3,000 lb of milk, one selling to A and the other to B? *Ans.* $8.71 more for man selling to B

5. A dealer buys 1,000 lb of 4 per cent milk at 9 cents a qt for 3.5 per cent milk, plus 0.1 cent a qt for each 0.1 per cent over 3.5 per cent. He sells 300 qts at 10.5 cents a qt. The balance is sold in the form of butter at 75 cents a lb (1 lb butterfat = $1\frac{1}{6}$ lb butter). Figuring that skim milk tests 0 and cream from which butter was made tests 30 per cent, how much must he get per hundredweight of skim milk to avoid loss on the whole deal? *Ans.* 8.4 cents per cwt for skim milk

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CHAPTER 18

Ice Cream Making

History and Extent of the Industry. Not much is known about the history of ice cream. It is probable that it developed from the freezing of water ices in Europe in the sixteenth and seventeenth centuries. Jacob Fussell, a milk dealer, of Baltimore, Maryland, really started the commercial ice cream business in this country in 1851 in order to use up his surplus milk, a very common reason for going into the ice cream business. The Government report shows a production for 1957 of 645,000,000 gal. This is approximately 4 gal for every man, woman, and child in the country. It required 6.7 per cent of the milk production or about 8½ billion lb. Mechanical refrigeration, the invention of new machinery, and the discovery of new methods have revolutionized the industry. A relatively recent development within the industry has been the centralization of manufacture in large plants, especially large companies controlling a number of plants. Although there are still many small plants, there are now many making 2 to 10 million gal per year.

Another fairly recent development is the so-called soft-serve ice cream stand. These are frequently controlled on an ownership or lease basis by large operators. The stands are generally located on sites on the outskirts of large towns or cities, where the traffic is heavy and plenty of parking space is provided. Though hard ice cream may be sold for take-home purposes, most of it is served soft from the freezers. Many types of servings are used. In the northern part of the country, most of these stands close for the winter.

Definition of Ice Cream and Other Frozen Desserts. *Ice cream* is a frozen mixture of various dairy products, sweetening, stabilizer, and

various flavorings. It generally but not always contains added coloring. It may but does not usually contain eggs. Ice cream and other frozen desserts are usually typed by their flavor, composition, or method of freezing. *Plain ice cream* is usually vanilla ice cream or a product requiring relatively small amounts of liquid flavoring, such as coffee, mint, etc. *Chocolate ice cream* requires a considerable quantity of cocoa or chocolate liquor for flavoring. It is generally prepared as a separate mixture with some of the butterfat being replaced by the cocoa fat. More sugar is also used than in plain ice cream. *Fruit ice cream* gets its name from various fruits used. Since the quantity of fruit required is considerable, the butterfat is generally lower in fruit ice cream than in plain ice cream. *Nut ice cream* also gets its name from various nuts used in flavoring plain ice cream mix. *Frozen custard, French ice cream, French custard ice cream,* are made from a modified plain ice cream mixture so that the weight of the finished product contains a minimum weight of egg yolk solids. *Ice milk* is made from the same ingredients as plain ice cream, except in different proportions. The butterfat content must be less than the minimum for ice cream and is generally in the range of that for whole milk. *Fruit sherbet* is a frozen mixture of dairy products, sweetening, stabilizer, such as citric, tartaric or lactic food acid and fruit flavoring. It may, but generally does not, contain a limited amount of egg solids. Fruit sherbet differs mainly from ice cream in that it is low in butterfat, contains more sweetening, is tart to the taste and has less overrun. *Water ice* is essentially the same as fruit sherbert, except that it contains no milk products or eggs.

Most of the states have standards for frozen desserts, which are found in Appendix K. The U.S. Food and Drug Administration also is developing standards which will apply to products shipped interstate.

Ingredients of Ice Cream. The ingredients used in ice cream must be selected and proportioned so as to give the ice cream the desired composition. The composition may vary considerably depending on the type of ice cream made and the section of the country and the various state standards.

Normal variations in ice cream are shown in the table on page 319.

The most important component of ice cream is the butterfat, which must be clean and fresh in flavor if good ice cream is to result. The source of the butterfat is one or more of the following: fresh sweet cream, frozen sweet cream, plastic or solid cream, whole milk, or un-

salted butter. If whole condensed milk is used, this also is a source of some milk butterfat. Sweet cream and milk are the butterfat sources to use in homemade ice cream; they are also important sources for commercial ice cream, though large quantities of the other products named above are also used.

Sweetening is the next most important constituent. Cane sugar is most commonly used. Good results are obtained also by combining cane sugar with sugar syrup, corn syrup solids, or corn sugar. The combinations usually have the additional advantage of being cheaper than cane sugar alone, and they improve the body and texture of ice cream. Other sugars in ice cream such as fruit sugars, maple syrup, and malt syrup are present in flavoring materials.

Normal range in composition		Approximate average
	Per Cent	*Per Cent*
Butterfat	8 to 20	12
Sugar	13 to 18	15.5
Serum solids	7 to 12	11
Stabilizer	0 to 0.5	0.3
Egg solids	0 to 2	0.3

Next in importance are the products which build up the milk-solids-not-fat (serum solids) and the total solids of the ice cream. These products give ice cream the desired body and texture and enhance its food value. In commercial ice cream such dairy products as plain condensed whole or skim milk, superheated condensed whole or skim milk, sweetened condensed whole or skim milk, and skim milk powder are used with good results. These products must be fresh and of good quality; otherwise they will detract from the flavor of the ice cream. In homemade ice cream, eggs, cornstarch, evaporated milk, or sweetened condensed milk are used. These products, sometimes called fillers, improve the body of ice cream and prevent it from melting too quickly.

Some ice cream companies do not use a stabilizer, but most of them do. A stabilizer is a substance added in very small amounts to combine with the water in the mix and make the ice cream smooth and firm. Gelatin and sodium alginate in various forms are the most common and satisfactory stabilizers. They give the ice cream a smooth texture, and prevent coarseness which is caused by the separation of large ice crystals. Certain vegetable gums and Irish moss also are used. In the selection of a stabilizer, one should make

a choice on the basis of the effect in ice cream, as well as the price. Very little stabilizer is needed, and the price per pound is relatively high. Hence, only a small amount is used, usually less than 0.5 per cent. In homemade ice cream, which is usually eaten promptly, a stabilizer is not necessary.

Egg-yolk solids are frequently used to improve the flavor, texture, and whipping properties of ice cream. Fresh egg yolk may be used, as well as frozen and dried egg yolk. Egg-yolk solids improve the quality of ice cream and should be used if the added cost is justified by the price received for the ice cream. In making so-called French ice cream, the state law generally specifies the minimum quantity of egg solids that must be used, because egg solids account for the name "French Ice Cream."

Ice cream powders or improvers have been used to a limited extent, principally to make a smooth and firm-bodied ice cream. There are many of them on the market; they vary somewhat in composition but the principal constituent of an improver seems to be its enzyme, which is often accompanied by a gum, together with sugar and starch, as fillers.

The ingredients must be so proportioned into a mix that a product of the desired composition is obtained. There are several methods of calculating and balancing a mix, but it is not within the scope of this text to explain them. This topic is left for a specialized course in ice cream making. Sample mix formulas are as follows:

	A	*B*
1.	30.0 lb 40 per cent cream	31.4 lb 40 per cent cream
	50.8 lb 3.7 per cent milk	40.0 lb 3.7 per cent milk
	or	or
	35.0 lb 40 per cent cream	35.0 lb 40 per cent cream
	45.8 lb skim milk	36.4 lb skim milk
	and	and
2.	15.0 lb sugar	15.0 lb sugar
3.	3.6 lb powdered skim milk	13.0 lb condensed skim milk
4.	0.3 lb powdered egg yolk	0.3 lb powdered egg yolk
5.	0.3 lb stabilizer	0.3 lb stabilizer
	100.0	100.0

These combinations contain 14 per cent butterfat and 9.5 per cent serum solids. It is possible to calculate all sorts of combinations.

The selection of flavor is an important item. There are many flavors and fruit combinations on the market and several grades of

each. The common flavors are vanilla, chocolate, coffee, maple, caramel, strawberry, cherry, pineapple, peach, and orange-pineapple mixture. Chopped walnut meats are frequently used with the coffee and maple flavors. Bakery and candy products commonly are used. There are a number of imitation vanillas on the market that give good results but, of course, the pure vanilla is more desirable. Cocoa and chocolate liquor are used for chocolate ice cream. It is common practice to buy prepared coffee and caramel syrups rather than to make them. An artificial preparation has been used in the past for maple flavor but pure maple syrup or concentrate gives better results and a truer maple flavor. Most of the preserved fruits need to be toned up a bit with citric acid and sometimes with a little fruit flavor. Of course, only unfermented fruit and sound, nonrancid nuts can be used. The freezing of certain fruits in cold storage has become important and these are most commonly used. The true fruit flavor is preserved better when freezing is practiced than when the fruits are put up in sugar syrups or otherwise preserved.

Ice Cream Equipment. Major equipment consists of the mixing tank, pasteurizer, homogenizer, cooler, storage tank, freezer, fruit feeder, and mechanical refrigeration. Mechanical refrigeration is based on the fact that a liquid absorbs heat as it vaporizes. There are several refrigerants used in the various types of mechanical units, but liquid ammonia is the most common one. It "boils" or vaporizes at temperatures below zero, depending on the pressure maintained in the system. For freezing, the refrigerant is pumped by a compressor through the jacket of the freezer or anywhere else in the plant that refrigeration is needed. For example, after the soft ice cream from the freezer is packaged, it is placed in the hardening room. These rooms are cork insulated and are refrigerated by expanding liquid ammonia through plates or coils after which the cold air circulates through the room. For making novelties, such as chocolate-coated bars and popsicles, the expanded ammonia is circulated through calcium chloride brine. These items are made in molds, the molds being passed through the brine tank.

In addition to the major pieces of equipment, there are ice cream brick making equipment, packaging machines, can washers, delivery trucks, and laboratory equipment. Nearly all manufacturing equipment is of stainless steel construction.

Processing the Mix. By this term is meant making the mix and preparing it for freezing. A plain stock mix from which any flavors can

be made, including cream, milk, skim milk powder, sugar, and gelatin, will be used in describing this process. It may be said at the start that different methods of processing ice cream mixes are used in different plants. It is probable that there are several methods by which equally good results may be obtained. A common method is to place the milk and cream in the mixing tank, which is a tank or vat provided with an agitator and a jacket for hot water. The skim-milk powder and gelatin, mixed dry, are then put in. Heat is turned on, and the mixture is heated to about 110° F, at which point the sugar is added. It is believed that the sugar dissolves more easily if put in at this temperature. It is a common practice to mix the gelatin with the sugar. The whole mix is then heated to 155° F and held for 30 minutes, to pasteurize it.

In many of the larger plants, the mixture is put together and partially heated in tanks and pasteurized in a continuous flow through short-time high-temperature pasteurizers. It is then pumped, at 1,500 to 3,000 lb pressure, through the homogenizer, whence it goes over a cooler which reduces its temperature to 50° F or below. It then goes into large insulated tanks, known as aging or storage tanks.

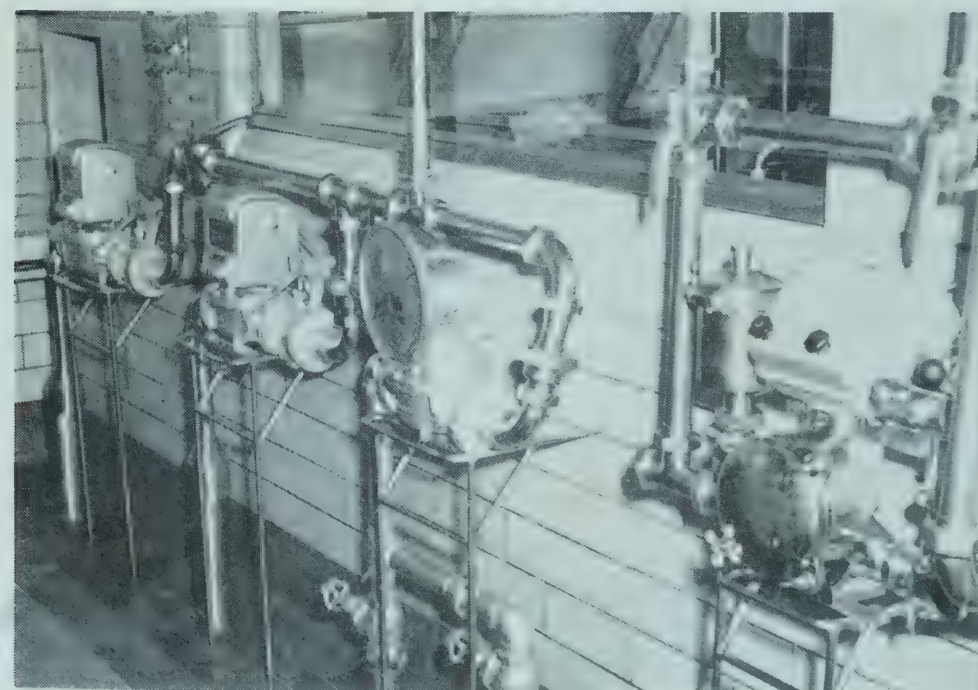

Fig. 100. Siemen meter with air eliminator for the metering of fluid dairy products and Neptune meters for water and syrup used in mix making, 1958.

Fig. 101. Mixing, pasteurizing, and storage of ice cream mix.

The mixture is held close to 40° F in the storage tanks, preferably for at least 24 hours, to allow it to blend and thicken up so that it will make an ice cream of good body with proper overrun. Just what happens during the aging period is not definitely known, but it is thought that the gelatin sets into a soft jelly and the milk proteins absorb water and swell. Much ice cream is made at present from fresh mix that has not been aged, but this practice is dependent upon many factors for success.

Freezing the Mix. BATCH FREEZER. The mix is run into the freezer at about 40° F. The freezer should not be more than half full. All flavors are added at the freezer. Vanilla is usually added at the rate of 2 to 4 oz per 10 gal of finished ice cream, depending on the grade of vanilla. It is added as soon as the mix has been put into the freezer. Vanilla sometimes is used with other flavors to make them more pronounced. Fruits and nuts are added, through the "fruit hopper," when the mixture is partly frozen in order to insure a

better distribution throughout the mix and to prevent curdling of the mix by acid fruits.

In a direct-expansion freezer, ammonia pressures equivalent to temperatures of zero to 10° F below zero should be used. The refrigerant is turned on and the dasher started. The mixture is frozen a little harder than it is intended to be when drawn from the freezer, and is cooled to about 24° F, depending on the composition of the mix. The ammonia then is shut off and air is whipped into the mixture; the purpose of this action is to get the proper swell or overrun (as it is commonly called), or weight per gallon of ice cream, and the right consistency at the same time. Many of the present-day freezers obtain the desired overrun during the freezing time and thus do away with the whipping period. The overrun is made up of air and equals the gallons excess of ice cream over gallons of mix from which it was made, or, on a weight basis, the difference between the weight of a certain volume of the mix and the weight of an equal volume of ice cream. To get the per cent overrun, this difference is divided by the weight of the ice cream used in making the test. For example,

$$\text{Weight of 1 gal of mix} = 9.25 \text{ lb}$$

$$\text{Weight of 1 gal of ice cream} = 5 \text{ lb}$$

$$9.25 - 5 = 4.25$$

$$4.25 \div 5 \times 100 = 85 \text{ per cent overrun}$$

The per cent overrun is calculated on a volume basis by dividing the gallons of overrun by the gallons of mix. Various testers to determine the per cent overrun are on the market. From 80 to 100 per cent is the usual overrun obtained; this means that the ice cream weighs 4.5 to 5 lb to the gal. The incorporation of the right amount of air, as in the case of bread and other baked products, is essential for the ice cream to have good eating property. Note Appendix J for the weight per gallon or overrun standards for various states which protect the consumer from buying ice cream with excessive overrun.

It should take 6 to 10 minutes to freeze the ice cream, as described above. It is then drawn from the freezer at 21° to 23° F into packing cans or brick slabs, in a semifrozen condition, and another batch is run into the freezer.

CONTINUOUS FREEZER. When ice cream is made in a continuous freezer, the mix is pumped slowly but steadily into the freezer. The

desired overrun is secured by making the desired adjustments. The stiffly frozen ice cream comes from the freezer in a continuous stream and is packaged as it emerges. Flavoring materials, which will readily pass through the mix pumps are added to the mix just prior to freezing the ice cream. When fruit or nut ice creams are made, however, the flavoring material is combined with the ice cream, by means of a suitable attachment, as the frozen product leaves the freezer. Ice cream frozen in a continuous freezer has the advantage of being very firm when packaged and it is uniform in weight and texture.

HAND FREEZER. When homemade ice cream is frozen in a tub freezer, with salt and ice, the first step is to pound or chisel the ice very fine. A No. 2 rock salt should be at hand. Pack the freezer about half full of ice, and then alternate layers of salt and ice until the can is covered. It will take about 1 part of salt and 12 parts of ice. Two or three cupfuls of lukewarm water are then poured over the salt and ice to start the formation of a brine more quickly. The formation of this brine, dependent upon the melting of the ice by the heat from the mixture in the freezer can, is necessary to freeze the ice cream. The dasher should be turned slowly until it is just be-

Fig. 102. Freezing and packaging bulk ice cream, 1958.

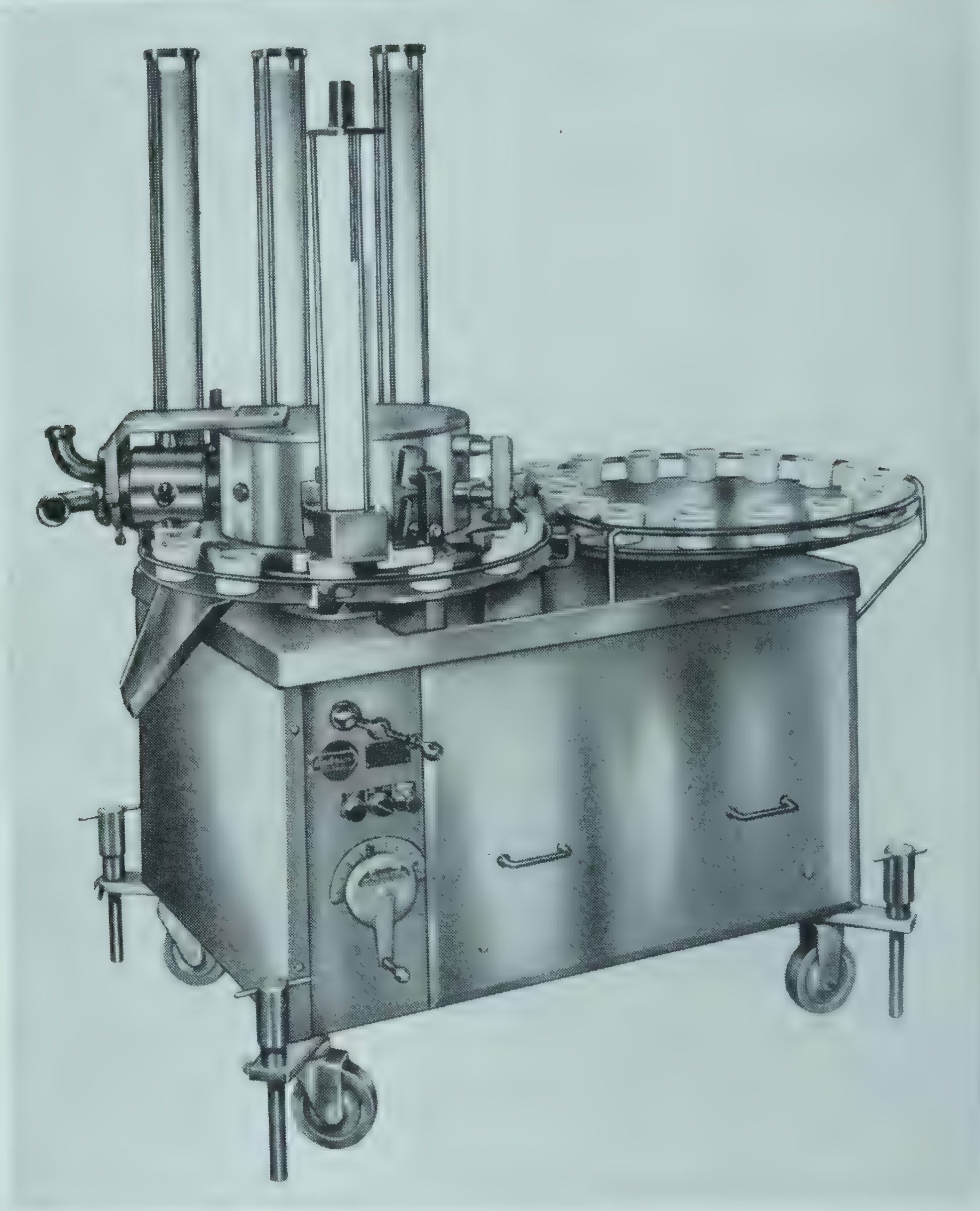

Fig. 103. Filler for ice cream cups of varying size. (Courtesy Anderson Bros. Mfg. Co.)

ginning to turn hard, after which it should be turned faster to whip the necessary air into the ice cream. Unless the ice cream is to be eaten immediately, one should stop freezing when the ice cream has the same consistency as that from a power freezer, and then pack it for hardening. If the ice cream is frozen hard, most of the overrun is lost.

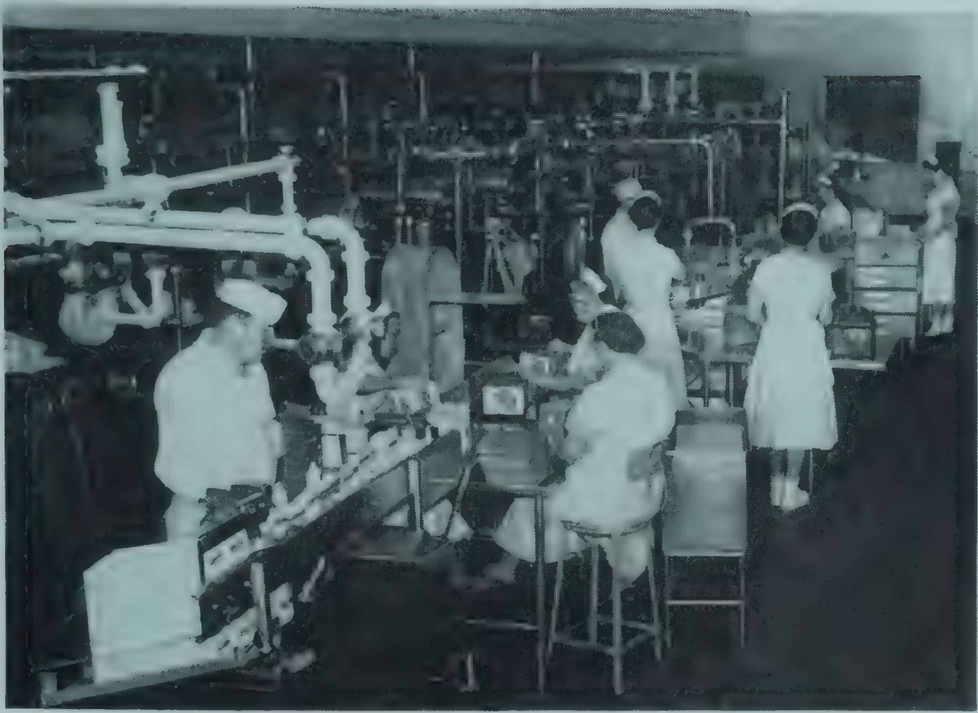

Fig. 104. Freezing and packaging ½ gallons, pints and bulk, 1958.

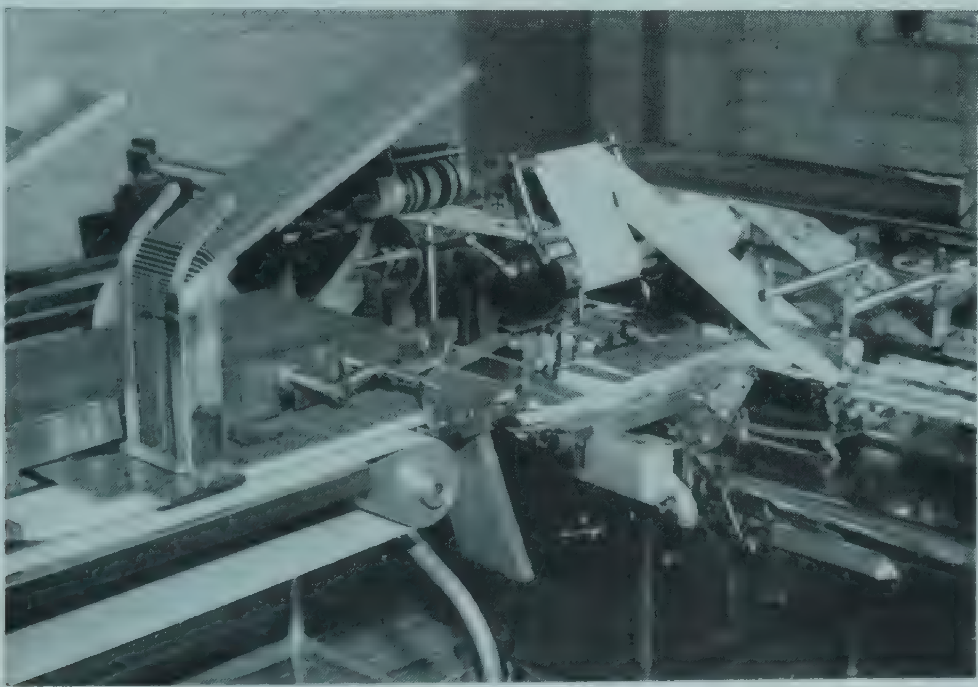

Fig. 105. Making ice cream sandwiches, 1958.

Fig. 106. Brine tank method of freezing ice cream stick novelties.

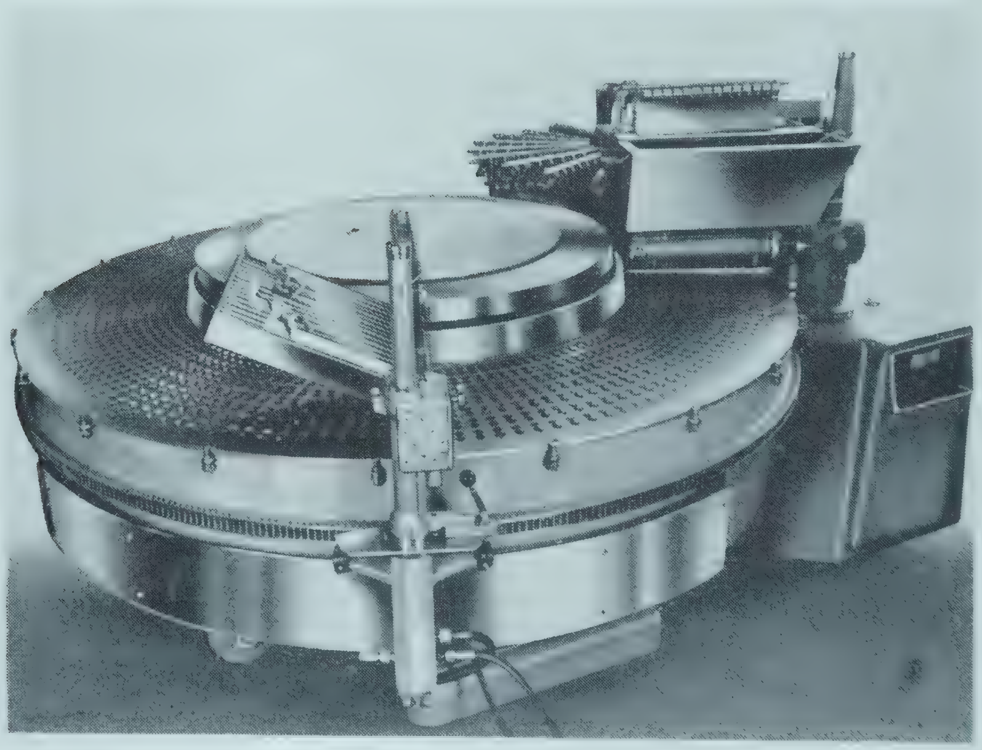

Fig. 107. Gram machine for freezing ice cream novelties. (Courtesy Anderson Bros. Mfg. Co.)

Packaging. Early in the history of the business, the metal can was used for bulk, the 5-gal size being in most common use. Later the metal can gave way to paper, the $2\frac{1}{2}$-gal size being most common. Brick ice cream was made by filling 2-gal metal slabs or molds and after hardening the ice cream was sliced into quart and pint bricks and individual slices. Fancy forms were made by filling metal molds of various designs with semi-hard ice cream, hardening, and removing by immersing the molds in hot water.

In recent years, the trend has been away from bulk ice cream to pint and half gallon packages. These may be filled directly from the freezer, using a battery of freezers for multiflavored packages, or by running the soft ice cream through a packaging machine. There are also machines for making "individual slices" from soft ice cream. The ice cream cup in varying sizes also is filled by machine. The so-called "brine tank novelty," such as various popular bars on a stick, is made in molds passed through a tank of refrigerated brine.

Thus it can be seen that the ice cream business has become much more complicated with the passing of time, and more help is required than for a bulk operation.

Fig. 108. Ice cream hardening room.

Fig. 109. Decorated ice cream cake.

After the ice cream is packaged, it is placed in mechanically refrigerated, insulated rooms to harden. The temperature of these rooms is $-20°$ F or lower. Various methods of very fast hardening, such as passing the packaged ice cream through a blast of very cold air in a tunnel, also are used. Smaller packages may be hardened in less than an hour. The hardened product is then stacked in the refrigerated room. Fast hardening makes for superior texture of the ice cream.

Marketing Ice Cream. Ice cream is marketed in a variety of ways. After it is first frozen to a solid condition in the hardening room, it is taken by refrigerated trucks to the retail outlet, that is, the soda fountain, hotel, or restaurant, where it is dispensed from a mechanically refrigerated cabinet. Modern refrigerated trucks usually are

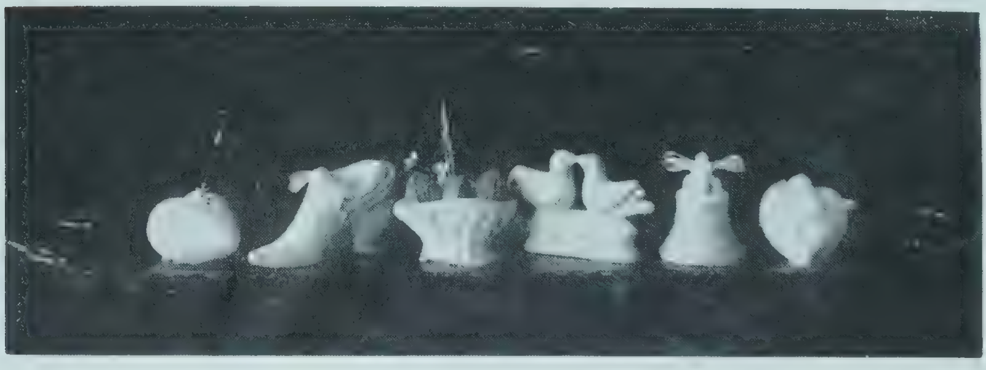

Fig. 110. Individual fancy forms.

cooled by mechanical refrigeration. Dry ice (solidified carbon dioxide) sometimes is used. It also is used to refrigerate shipping containers and for home delivery of fancy forms, cakes, and the like. In cities and along heavily traveled highways, the ice cream store or roadside dairy cottage frequently is seen. The majority of ice cream manufacturers, however, still deliver their ice cream by truck to retailers, such as proprietors of drug stores, candy kitchens, roadside stands, restaurants, and hotels. Time was when the drug store was the principal outlet, but now the chain store or supermarket is the manufacturer's big customer.

Characteristics of Ice Cream. The score card used by the American Dairy Science Association for scoring ice cream is made up of the following items, with their perfect score allotments:

Flavor	50
Body and Texture	25
Bacteria	20
Package and Color	5
	100

The flavor should be and is allotted the largest number of points on the score card. Because ice cream usually is eaten because of its flavor and refreshing qualities, acceptance of the product depends largely on the flavor. It should taste clean and creamy, be well blended, and of proper sweetness. Fruits and nuts should be evenly distributed throughout the package. Some of the common defects to guard against are too high or too low sweetness; too much or too little flavoring; poor flavoring; or off flavors due to poor quality dairy products.

Next to flavor, one seeks a smooth texture and creamy body in ice cream. Defects sometimes noted are coarseness; presence of ice crystals, lactose crystals, butter or stabilizer lumps; crumbly or fluffy body, and sogginess.

The bacterial content of ice cream is important as an indication of the desirability of the ingredients and the way they have been handled. Careful cleaning of the cooler, pipe lines, vats, and freezers and careful pasteurization are essentials in producing ice cream of a low bacterial count.

The color of ice cream should be uniform throughout, not wavy or uneven. The shade depends on the flavor and the local demand for color in different flavors. The package should be neat and attractive.

QUESTIONS

1. State in outline form the salient facts concerning the history of the ice cream business.
2. What is "plain ice cream" and how does it differ from parfait or French ice cream?
3. What is the difference between an ice and a sherbert?
4. What are the factors that determine the composition of the ice cream that the company manufactures?
5. What are the sources of the butterfat for ice cream?
6. What are the sources of ice cream sweetening?
7. What are the sources of milk solids-not-fat for ice cream?
8. What is the function of a stabilizer?
9. What purpose do egg yolks serve in making ice cream?
10. What is an ice cream "improver"?
11. What are the more common ice cream flavorings?
12. List the equipment used in commercial ice cream manufacture.
13. What is the function of the homogenizer?
14. What are the differences between a batch and a continuous freezer?
15. Explain how mechanical refrigeration is used in freezing ice cream.
16. What are the basic factors to consider when calculating an ice cream mix?
17. List the steps involved in the preparation of the mix.
18. What is meant by ice cream overrun and why is it so important?
19. How are fruit and nut flavors added to ice cream when the continuous freezer is used?
20. How would you make ice cream in the home with a hand freezer?
21. What package sizes are commonly used in commercial ice cream manufacture and how are they filled?
22. What is a "brine tank novelty"?
23. What is the function of the hardening room?
24. How is ice cream delivered to the retail outlet and what is the principal type of outlet?
25. How is ice cream quality measured?

PROBLEMS

1. (*a*) Five and a half gallons of mix made 10 gal of ice cream.
(*b*) A gallon of mix weighs 9 lb and a gallon of ice cream made from same weighs 4.75 lb. Figure the per cent of overrun by volume and weight. *Ans.* (*a*) 81.81 per cent, (*b*) 89.47 per cent

2. Figure a 100-lb ice cream mix, testing 12 per cent butterfat, 38 per cent T.S., 15 per cent sugar, and 0.4 per cent gelatin, using 40 per cent

butterfat cream, skim milk powder, sugar, and gelatin. See Appendix H for composition of ingredients.

3. What must the cream in the following formula test, if the ice cream made from it is to test 14 per cent butterfat? Formula: 40 lb cream, 7 lb sugar, 4 oz gelatin dissolved in 4 lb water, 4 oz flavoring.

Ans. 18.02 per cent

4. Figure the per cent butterfat, M.S.N.F., and T.S., in the following formula: See Appendix H for composition of ingredients.

71 lb of 20 per cent cream
20 lb of skim condensed milk (unsweetened)
8.5 lb of sugar
0.5 lb of gelatin

Ans. 14.2 per cent butterfat, 10.40 per cent M.S.N.F., 33.55 per cent T.S.

5. An ice cream mix weighs 9.2 lb to the gal. A gal of ice cream from this mix weighs 4.5 lb. Had the overrun been 10 per cent less, how much would a gallon of the ice cream have weighed? *Ans.* 4.73 lb

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CHAPTER 19

Buttermaking

Definition of Butter. Butter consists mainly of an agglomerated mass of milk fat brought together by a form of agitation called churning. The composition of butter is about as follows:

Butterfat	82–84 per cent
Water	14–16 per cent
Salt	0–4 per cent
Curd	0.1–3.5 per cent

There are present traces of other milk constituents and fat soluble materials, such as carotene and butter color, when used. Butter containing no salt is commonly known as "sweet butter." Butter must contain at least 80 per cent butterfat to comply with federal regulations.

Historical. Prior to 1856 buttermaking was strictly a farm operation. In 1856 the first small creamery and cheese factory was started in Orange County, New York, but it was not until 1871 that the first creamery for making butter was built in Iowa. Milk was delivered to the creamery and placed in vats for the cream to rise. The skim milk was drawn off at the bottom, leaving the cream for churning. About 1875 cream was separated by the deep setting system on the farm and the cream gathered and taken to the creamery. In 1879 power centrifugal separators were installed in creameries; milk was taken to the creamery and separated and the farmer took home the skim milk for feeding purposes.

By 1890, the hand-power farm separator came into use and the

Babcock test was discovered, which gave great impetus to buttermaking and had the effect of literally doing away with the skimming of milk at the creamery. The hand-separator system eventually gave rise to the large centralized butter factories, operating hundreds of cream stations throughout the countryside where the cream was delivered and shipped, sometimes hundreds of miles, to the "centralizer." This practice resulted in the receipt of much cream of inferior quality, which undoubtedly had a deleterious effect on butter consumption. This centralizer system is still in effect to some extent, but with the development of skim milk powder drying, and the demand for the product, the trend for some time has been back to the so-called whole milk creamery, where milk is delivered and skimmed, cream is made into butter, and skim milk into powder.

The high price of butter during World War II, coupled with the development of margarine made largely from cocoanut, cotton seed, and soybean oils (selling at half or less than half the price of butter), started a trend that has had a profound effect on the buttermaking business. A few government statistics will further clarify these statements:

During the period 1925–1929 approximately 30 per cent of all milk used for buttermaking still went into farm made butter, whereas in 1957 this figure had dropped to 9 per cent. In the period 1925–1929, 31 billion lb of milk a year went into creamery butter, whereas in 1957 this had dropped to 28 billion lb, in spite of a large increase in population. This amount is about 22 per cent of all the milk produced in the country, which shows that buttermaking is still big business. Per capita consumption of butter started to drop in 1941 from 17 lb per capita per year in 1940 to 8.7 lb per capita in 1956—the same as the per capita consumption of margarine.

Other figures showing the present trend to the whole milk creamery system are as follows: as late as 1930 virtually all factory butter was made from farm-separated cream, whereas in 1956 slightly less than half was made from farm-separated cream and slightly more than half made from whole milk separated at the creamery.

Preparation of the Cream for Churning. The factors on the score card that measure the quality of butter are flavor, body, color, salt, and package. Forty-five points out of the hundred are given to flavor, since butter is used largely because of its flavor-giving properties. The flavor of butter may be affected by almost any, or all, of the steps in its production, from the milking process to the packing

and storing of the butter. The chances of making good butter are greatly improved if conditions have been satisfactory up to the time when the cream arrives in the storage can or vat. The next important step is to cool the cream at once to 50° F, or below, and hold it there until time to prepare it for churning. The main cause of poor quality in butter is the churning of old, sour cream which, in turn, is a result of improper cooling. The following are some of the main faults in cream cooling on the farm: (1) trying to cool cream in air, (2) failure to use enough water, (3) the use of water that is too warm, (4) mixing warm cream from the separator with cooled cream, (5) and cooling the cream in foul-smelling cellars or other places where the air has a bad odor. These problems do not arise if milk is delivered daily to the creamery for skimming, which explains why this system results in better butter than the gathered cream system. If cream is delivered to a creamery, it should be delivered at least three times a week in summer and twice a week in winter. Cream may be in any one of the following conditions for churning:

1. Raw and sweet.
2. Raw and ripened.
3. Pasteurized and sweet.
4. Pasteurized and ripened.

In making creamery butter, a "starter" is used for ripening. To ripen cream with starter, the previously pasteurized cream is warmed to 70° F and 5 to 10 per cent by weight of starter is strained in. It is mixed well and left to ripen, probably 12 to 18 hours or until 0.2 to 0.4 per cent acidity develops.

An ever increasing amount of butter is made in creameries out of pasteurized sweet cream, and the public will doubtless come to like the flavor of this butter better than the ripened-cream flavor. The advantages of making butter out of this cream are that any disease organisms that may have been in the cream are killed, and the butter has excellent keeping properties. When butter is made for storage, it should be made out of pasteurized sweet cream. Every year, quantities of butter made from such cream are put into storage. Much of it is used as a source of butterfat in making ice cream.

Cream which arrives at the creamery already sour or fermented cannot be pasteurized successfully by the usual methods, unless the acid is destroyed by "neutralization" of the cream. Neutralization consists of adding to the cream the correct amount of an alkali, such as milk of lime, milk of magnesia, or baking soda dissolved in water,

in order to reduce the acidity to about 0.25 per cent. Neutralization and pasteurization (and sometimes a vacuum treatment) of the sour cream reduce the sour and fermented off-flavors but tend to leave the cream with a slightly flat taste. It is common practice, therefore, to add some starter culture to neutralized cream and ripen it slightly. Neutralizing sour cream makes it possible to produce a better-flavored butter, with better keeping quality, than would result from churning cream which was too sour. However, the butter quality will not be nearly as good as when made from fresh sweet cream.

The only remaining step in preparing the cream for churning is to get it to the churning temperature. This temperature may be 52°–58° F in summer and 58°–65° in winter. Cream should be at the churning temperature for at least 2 or 3 hours before churning, as it takes some time for cream to become tempered so that it will not change quickly, especially from a lower to a higher temperature.

The Churning Process. Equipment for performing this process is known as a churn. At favorable temperature, cream subjected to continuous agitation will separate into essentially two parts, butter composed mainly of butterfat and buttermilk consisting mainly of water and milk solids-not-fat. The physical chemistry involved is not entirely understood and will not be discussed. When the butter granules begin to separate, it is said that the "breaking point" has been reached. Churning continues a little longer until the tiny granules adhere into small masses.

The main body of buttermilk must be removed and buttermilk adhering to the butter granules washed away. The butter must then be salted, if salt is used, and "kneaded" into a compact mass for packing.

For creamery use churns having a capacity of 1,000 lb of butter or more are used. The development of these churns has been from the wooden churn with rolls to the wooden no-roll churn to the metal no-roll churn.

The wooden churns are drums rotated in a horizontal position. Shelves protrude out from the inner wall. In the case of the roll churn, two horizontal, slightly concaved rolls set closely together extend lengthwise of the churn. In the no-roll churn there are more shelves, vanes, or round horizontal stationary rolls. All these devices serve to provide the necessary agitation for the cream as the churn is revolved, and following the washing of the butter, they work the butter into a compact mass, at the same time incorporating the salt,

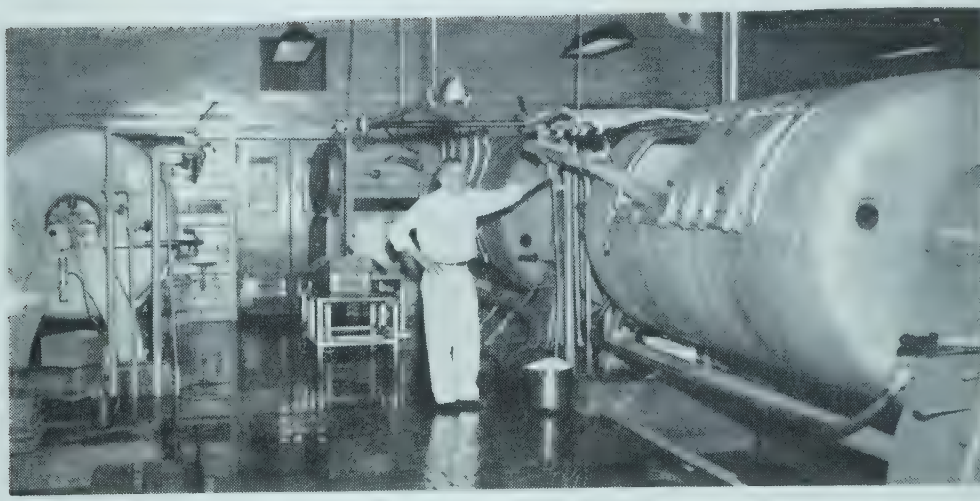


Fig. 111. Large power churns and churn room.

when used. Cubical metal churns are also in use. These churns have no inside parts. They are in a frame supported at two opposite corners; as the churn is rotated, there is a violent "tumbling" effect by which churning and later working of the butter is accomplished. The steps of the entire creamery churning process are described below.

PREPARE CHURN. The churn must be scalded and thoroughly cooled with cold water. The pores of the wood surface must be filled with water to prevent cream and butter from sticking to the wood.

PLACE CREAM IN CHURN. Sweet cream should churn in 40 to 50 minutes and ripened cream in 30 to 40 minutes. This may mean having the cream at about 48° F in summer and 55° F in winter. When cows are on pasture in summer, the butterfat is softer. The spread between the temperature in the churn and in the churn room is also greater; hence the lower churning temperatures in the summer. The following cream factors are very important and affect the time of churning, the butterfat lost in the buttermilk, and the condition of the butter. Because most of the buttermilk is dried and used for animal feed or in bakeries, and because butterfat is an expensive ingredient, it is obvious that the churning operation should put the butterfat into butter and not lose it in the buttermilk.

Casein becomes coagulated in ripening cream, so that sour cream churns more easily than sweet cream. Thirty to thirty-five per cent butterfat is the ideal test for cream for churning. Cream with too low a butterfat test churns with difficulty; cream testing 40 per cent or more does not handle well and too much butterfat is lost in the

buttermilk. The churn should be filled only half full of cream for best results.

ADD BUTTER COLOR IF REQUIRED. This will depend on the prevailing breed of cattle in the area, the season of the year, and the market requirements.

CHURN UNTIL BUTTER GRANULES FORM AND COALESCE TO SOME EXTENT. When churning is done, these masses of granules will be seen floating on the buttermilk when the churn doors are opened for examination.

DRAIN BUTTERMILK. After draining buttermilk, rinse inside of churn and butter with water at about same temperautre as buttermilk and let this milky water run through churn outlet gate to drain.

ADD WATER. Add about same amount of water as cream to the churn. Water should be same temperature as buttermilk if consistency is right, a little colder if butter is a trifle soft, or warmer if butter is too firm. Give churn 3 or 4 revolutions and draw off wash water.

SALT. Sprinkle butter granules with salt if salt butter is being made. Salt according to market requirements, generally about 2 per cent of weight of butter. Revolve churn at prescribed speed (slower than churning) to incorporate salt and to compact the butter granules.

SAMPLE BUTTER FROM CHURN AND TEST FOR MOISTURE. The aim is to have the finished butter conform to the federal standard as closely

Fig. 112. Churning is completed. View of butter granules before draining the buttermilk. (Courtesy Sugar Creek Creamery Co.)

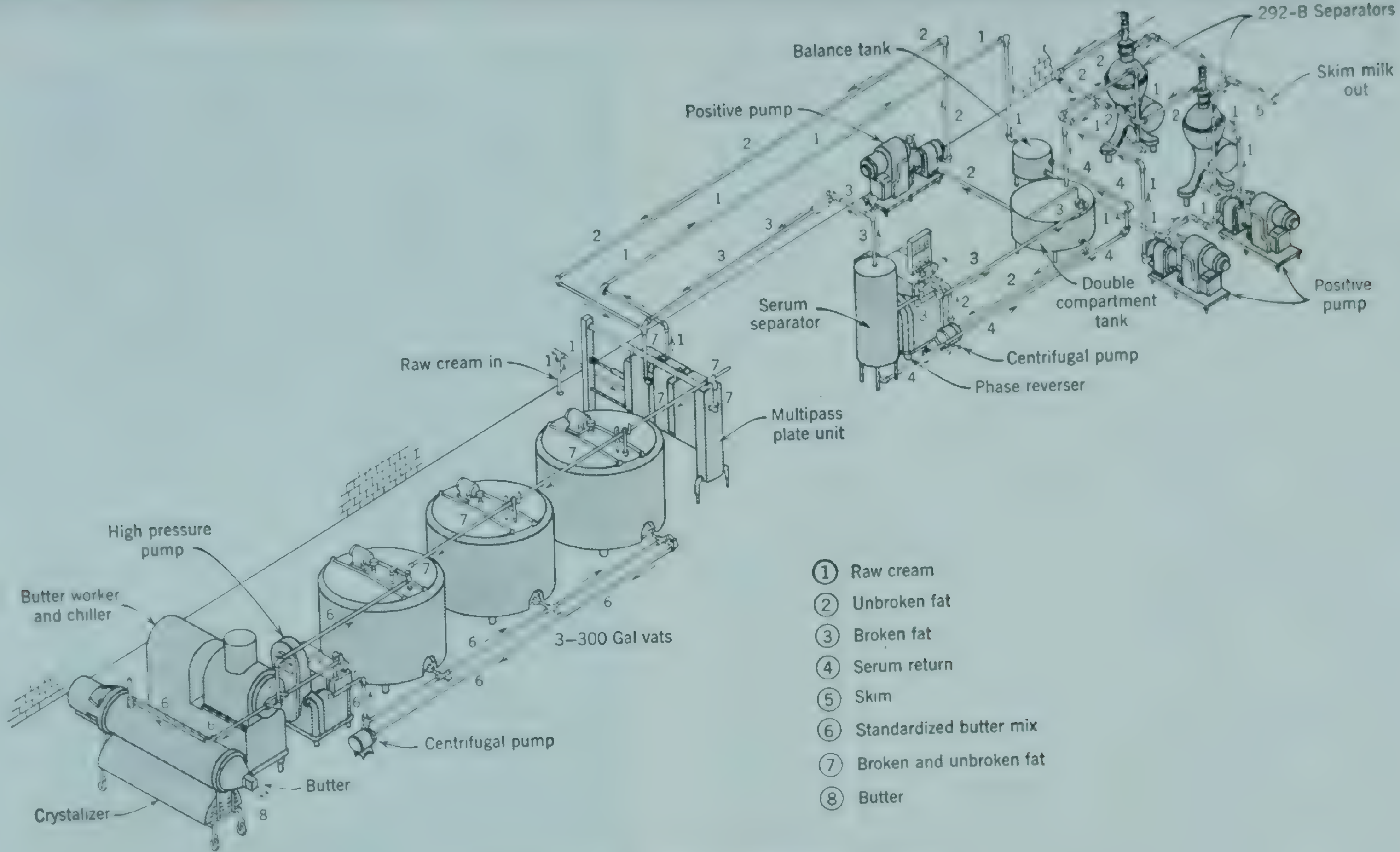
as possible. If moisture test shows butter to be below 15.8 per cent, add water enough to the churn to bring it to this figure, and work it into the butter. It is doing this and preventing loss of butterfat in the buttermilk that determines the overrun and quite largely the profit or loss on the operation. Overrun is the difference between the pounds of butterfat put into the churn in the form of cream and the pounds of butter packaged. It consists of moisture, salt, and curd and is expressed in percentage. Thus if 80 lb of butterfat make 100 lb of butter, the overrun is 20 lb or 25 per cent. Since butter must contain at least 80 per cent butterfat, this is the maximum overrun that can be obtained legally.

REMOVE THE BUTTER AND WASH CHURN. Rinse churn with hot water to melt butterfat sticking to churn. Drain and add more hot water containing a mild alkali. Rotate churn in high gear for 8–10 minutes. Drain. Fill churn ¼ full with scalding water and rotate 10–15 minutes. Drain. Leave gate open and doors opened upward. Prior to use, rinse with scalding water, followed by cold water or if time is a big factor, rinse with a cold 100-parts per million chlorine solution.

Continuous Buttermaking. From what has been said, it can be seen that the batch method of making butter is time consuming, composition is not easily controlled, churns are not easy to keep clean, and the removal of the butter from the churn is a laborious and not strictly a sanitary operation. For these and other reasons, a continuous method of buttermaking, suitable for plants making a million or more pounds of butter per year, has been developed by two of the large dairy equipment companies, and a number of installations are now in use.

The steps involved in the two processes are essentially the same, although the procedures followed are a little different. The following are the steps:

1. Milk is first separated to reproduce a cream consisting of about 40 per cent butterfat.
2. The cream at that butterfat content is either destabilized or the cream is reseparated to about 80 per cent butterfat and destabilized. Destabilization means breaking the emulsion of the butterfat globules and cream by destroying the film surrounding the globules, thereby permitting them to coalesce later in the process. This is accomplished by pump agitation of the cream under pressure, using special equipment for the process.
3. Using a special centrifugal separator, the cream is concentrated to about 90 per cent butterfat content.



Creamery Package Continuous Buttermaking Process
for Fresh or Sweet Cream. 2000 Pounds per Hour.

Fig. 113. Continuous buttermaking operation. (Courtesy Creamery Package Mfg. Co.)

4. The cream is then pasteurized in a continuous process at a temperature of 190°–200° F.

5. Following pasteurization, the concentrated cream is cooled to 110°–120° F and run into so-called composition control vats.

6. The next step is to test the cream for moisture, butterfat, and curd, and then by knowing the number of pounds in the vat, the required amount of water, salt, neutralizer, butter color, and starter flavor (if these are used), are added to give the desired composition. The same standards prevail as for butter churned in the conventional way.

7. Finally the prepared mix is run through what is called a butter chiller and then still under pressure is pushed through what is known as a crystallizer or texturator, where the butterfat is really crystallized and takes on the texture of butter.

8. Finally the butter leaves the machine in a steady flow and can be bulk packaged or printed and wrapped.

By using similar Creamery Package Manufacturing Company equipment, plus a "phase reverser," a device that frees the butterfat from its film protected globular form, it is possible to produce anhydrous or "dry fat" that is 99.96 per cent pure butterfat. This sub-

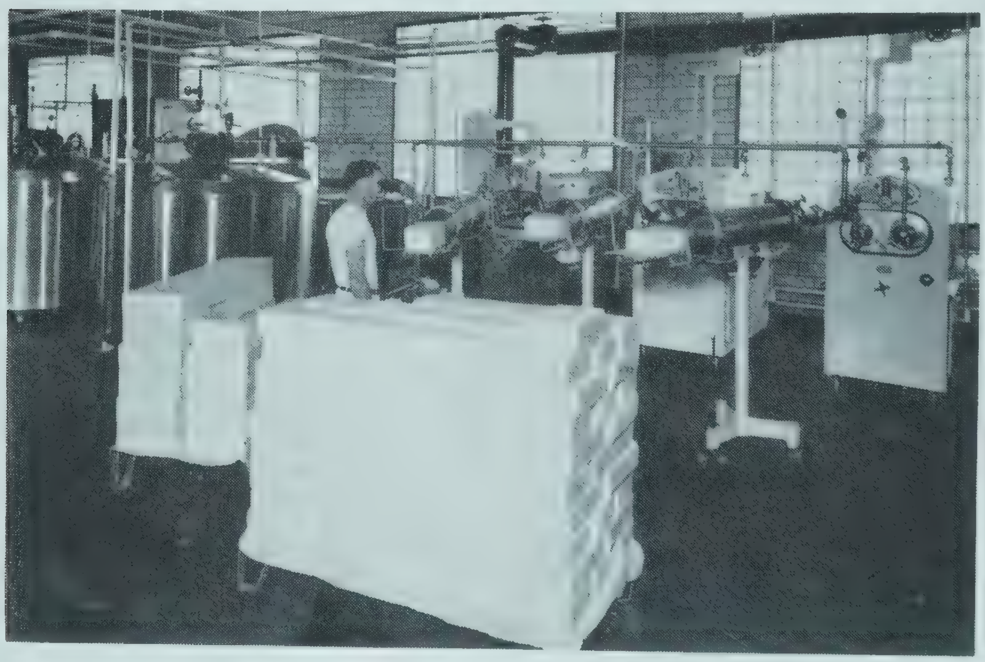


Fig. 114. Butter being extruded from texturator, continuous process. (Courtesy Cherry-Burrell Corp.)

stance makes it possible to store and ship a given amount of butterfat in the cheapest manner. The product is used particularly in foreign countries in manufacturing operations, notably ice cream making.

Farm Buttermaking. The process of making butter on the farm is essentially the same as for the conventional method of making it in the creamery. It is, of course, on a much smaller scale. When butter is made on the farm, cream should be churned at least twice a week, especially in summer.

Most of the butter produced on farms is made out of raw, ripened cream. The cream should be kept cold and sweet until the day before churning, when it is warmed to 70° to 75° F and placed in a warm room to ripen or sour until it has a mild acid flavor. The acid test should show that the cream contains about 0.4 per cent acid. This method of treatment is known as natural ripening. Sometimes the farm buttermaker has difficulty in getting the butter "to come." This problem may be due to any one or several factors, such as trying to churn at too low a temperature. The temperature should be 50° to 60° F, depending on various other factors. Sweet cream churns with greater difficulty than ripened cream. Since butterfat is softer when cows are on good pasture, it churns more easily. Cream from the higher-testing breeds churns easiest. Cream from cows advanced in lactation churns with difficulty as the butterfat globules are smaller and firmer. Cream testing 20 per cent butterfat or less, or even 40 per cent, churns with greater difficulty than cream testing 30 to 35 per cent butterfat.

For farm use several types of small churns are available, with the choice generally going to the barrel type. The butter must be worked outside the churn on a small hand churn worker. The butter then commonly is printed with a hand mold, wrapped in parchment, and put under refrigeration for home use.

Packaging and Marketing. The pound package, frequently containing 4 one-quarter pound prints, has become the most standard package for home consumption. Butter when removed from the churn is packed in boxes in cubes for chilling, after which it is placed in the hopper of a machine which automatically cuts the butter into the desired print and wraps it. The prints are packaged in corrugated cartons of varying size for the hotel and restaurant trade. Butter may be packed in 60-lb wooden tubs or 50–60 lb cubes. The butter tub, which was the common wholesale package in days gone by, has little use today. Machines are available for cutting butter

into individual pats for serving in hotels and restaurants, and considerable butter is marketed in this fashion.

Common market terms for butter are as follows:

Sweet cream butter–butter made of pasteurized sweet cream to which no starter has been added.

Ripened cream butter–butter made by starter ripened cream.

Sweet butter–butter which contains no salt.

Unsalted butter–butter to which no salt is added.

Salted butter–butter to which salt is added.

Probably three fourths of the butter produced in the United States is made in the Middle West states. Hence, it is sold through central markets in the larger cities, where butter dealers or brokers have established names and sell the butter to the retailer or food establishments. Because much more milk is produced in summer in the areas where butter is made, much of the butter is placed in storage in May, June, and July for use during the short season. Sweet cream butter, made from good quality cream, keeps very well for periods up to 8 or 9 months if the temperature is maintained at below 0° F.

Creamery butter is graded on the market according to its flavor, body, color, and salt content, according to specifications established

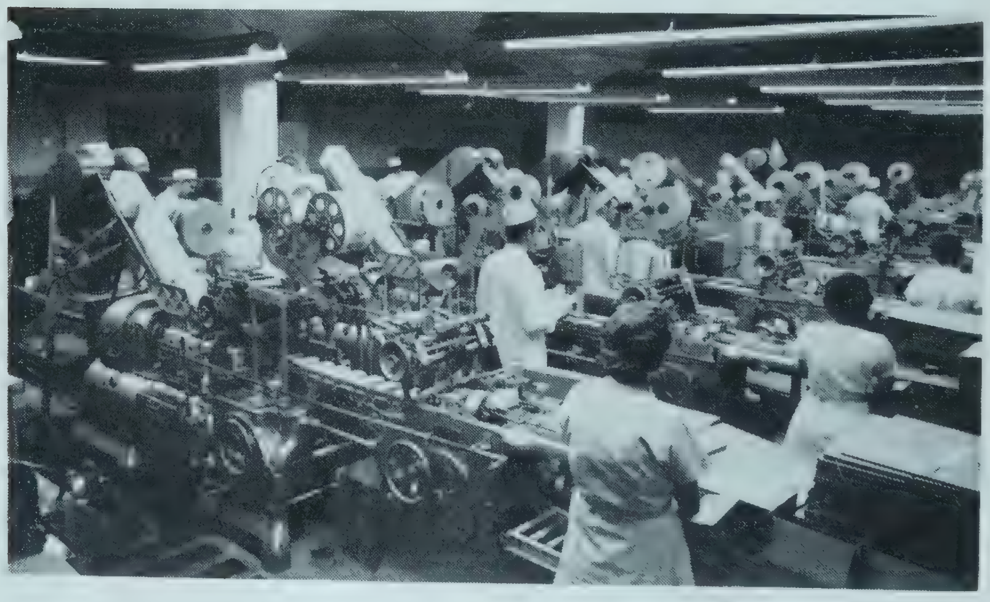


Fig. 115. Butter printing operation in a large plant. (Courtesy Sugar Creek Creamery Co.)

by the Agricultural Marketing Service of the U.S. Department of Agriculture.

QUESTIONS

1. What is the average composition of butter?
2. What is the federal standard for butterfat in butter?
3. List in outline form the various steps in the development of the butter business in this country.
4. What are the essential differences between the "gathered cream" and "whole milk" creamery?
5. What is the major criterion by which the consumer judges the quality of butter?
6. List the various types of cream that may be churned.
7. What is a "starter"?
8. What type of butter is best for long storage periods?
9. What is meant by the neutralization of cream and what is its object?
10. What are normal churning temperatures for summer and winter?
11. Why is it important to hold cream at the churning temperature for several hours prior to churning?
12. What is meant by the "breaking point" in churning?
13. List the different types of churns used in commercial butter manufacture.
14. What are the various steps involved in the churning process?
15. What is meant by butter overrun and why is it so important?
16. How is the churn cleaned following its use?
17. What seems to you to be the advantages of making butter by the continuous method as compared to the conventional churn method?
18. What is the essential equipment needed to make butter on the farm?
19. What are some of the factors causing difficult churning on the farm?
20. What are the common packages used for butter?
21. How are butter prints commonly made in the creamery?
22. What are the common market terms for butter?

PROBLEMS

1. If, at the end of a full day's run, 8,500 lb of milk had been received, testing 3.95 per cent, and from this milk 1,050 lb of cream testing 30 per cent butterfat were taken, how much butterfat (*a*) in the whole milk, (*b*) in the cream, (*c*) in the skim milk? (*d*) How many pounds of skim milk would there be? (*e*) What would skim milk test? (*f*) What per cent of the total milk separated was cream?

   Ans. (*a*) 335.75 lb, (*b*) 315 lb, (*c*) 20.75 lb, (*d*) 7,450 lb, (*e*) 0.27 per cent, (*f*) 12.35 per cent

2. A creamery buys 10,000 lb of 30 per cent cream and makes it into butter, getting a 22 per cent overrun. How many 63-lb lots of butter are made? *Ans.* 58.09

3. How many pounds of butter containing 82½ per cent butterfat can be made from 4,560 lb of 32 per cent cream, the loss in the buttermilk being 0.75 per cent of the total butterfat in the cream?
Ans. 1,755.46

4. How much money is due each of 3 patrons of a cooperative creamery when the following weights of milk are delivered by each: (*a*) 5,750 lb of 4.2 per cent, (*b*) 955 lb of 4.8 per cent, (*c*) 10,538 lb of 3.2 per cent, when 700 lb of butter are sold for $200.00, and cost of making is 3½ cents per lb of butter?
Ans. (*a*) $67.84, (*b*) $12.88, (*c*) $94.73

5. One thousand pounds of buttermilk testing 0.5 per cent is obtained from a certain churning. On the basis of a 20 per cent overrun, how many more pounds of butter could have been made had the buttermilk tested only 0.1 per cent? *Ans.* 4.8 lb

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CHAPTER **20**

Cheesemaking

Varieties of Cheese. Doane* reports that there are probably about 18 distinct varieties of cheese. There are, however, about 400 different names applied to these varieties. The names are commonly of local origin, the name of some town or community frequently being given to its product. The principal varieties of interest in this country, and the only ones that will be fully discussed here, are *cottage*, *Neufchatel*, and *Cheddar*. Other more or less common varieties are *Camembert*, *Limburger*, *brick*, *Roquefort*, and *Emmental*, or *Domestic Swiss*.

A Few Fundamentals in Cheesemaking. The milk used should be of high quality. It must be borne in mind that although the butterfat is an important component of every cheese except cottage, the casein is still more important. The first fundamental point is to get the casein, along with the other milk solids, separated from the bulk of the water in milk. This is accomplished by coagulating the milk, cutting the coagulated milk into small pieces and then separating the water, or whey, by draining and pressing. The curd must first be made firm enough to stand draining and pressing. This firmness is brought about either by adding rennet extract to the milk when it starts souring, or by heating the curd in the whey after the milk sours, or by a combination of the two methods.

The second point is that the cheese must take on its characteristic flavor. Flavor is caused by the bacteria and acid development in

* Doane and Lawson, "Varieties of Cheese; Description and Analysis," *U.S.D.A. Bull. 608.*

the cheese in the process of making and by the bacteria and mold development in the process of curing.

Cottage Cheese. Cottage cheese is made from skim milk. It should have a clean, mild, acid flavor, and a smooth, even texture. Some common undesirable flavors are unclean or too acid, and a grainy or lumpy body is a common defect. It is very important that all equipment and utensils be thoroughly washed and sterilized to prevent bacterial contamination, because cottage cheese is a very perishable product. Cottage cheese is made to some extent in the home but principally in the creamery or milk plant. In recent years, cottage cheese has become a major product of the market milk plant. The per capita consumption of cottage cheese was 4.5 lb in 1956 as against 1.5 lb in the 1935–1939 period. People seem to prefer the cheese with curd particles of varying size, and the manufacturer caters to their desires. Except for wholesale to bakeries, very little uncreamed cottage cheese is sold. The product is creamed to give a butterfat content of 4 per cent or better, this being the minimum amount prescribed by many state laws and by the federal government for interstate shipments. It is best when fresh but will keep in a cool place for several days.

CURD MAKING AND CREAMING PROCEDURES. *Small Curd Type (Acid):*

1. Following pasteurization at 143° F for 30 minutes or at 161° F for 16 seconds, skim milk is placed in the cheese vat. It is preferable to arrange the program so that the milk may be "set" directly after pasteurization and cooling, thus avoiding the necessity of cooling to a low temperature and reheating.

2. The setting temperature should be selected to give the desired cutting acidity at end of desired setting time. Suggested setting temperatures:

For 6 to 8 hours	86°–88° F
For 12 to 14 hours	72°–74° F

3. Add 1.5 to 2.0 per cent culture (use no rennet) and ripen to a firm-set curd in a covered cheese vat.

4. Cutting. Cut the curd when it shows a clean break and the acidity in the whey is 0.52 to 0.56 per cent, depending on the milk and type of curd desired. Cut with ¼-in. curd knives.

5. Heating. The cut curds are allowed to stand in the whey for 20–30 minutes, then heating starts. The heating or cooking then should be done in 1¾ to 2½ hours by means of gentle agitation in hot water jacketed vats. The curds are heated until the desired

firmness is reached. This firmness varies with milk from one plant to another and with seasons, and for these reasons it is not possible to specify exact cooking temperatures. The normal range will be between 110° and 125° F. Temperatures higher or lower than these may become necessary. The optimum cooking temperature should be selected by the cheesemaker. The desired firmness may be judged by taking a small scoop of curd and immersing it in cold water, then examining the curds to see if they are cooked all the way through and also that a handful of curd will "spring" lightly. Curd is to be discarded after examination.

6. Drain. Whey is drawn off as soon as the heating is discontinued, until the exposed curd occupies about ⅔ of the surface.

7. Washing. First wash water should be about 70° F. Water colder than 70° F is to be avoided for the first rinse. Drain. Second wash water should be between 50° and 60° F. Drain. Final wash water should preferably be 35° F and not exceed 38° F. Drain until water ceases to run freely from trenched curd.

8. For plain (uncreamed) cheese, the curd may be packaged directly from the vat, after draining sufficiently to obtain not more than 80 per cent moisture; or it may be placed in straight-sided curd cans for storage in the cold room and packaged at a later time.

9. For creamed cottage cheese, the curd may be creamed in the vat, provided the temperature of the packaged cheese is not over

Fig. 116. Packaging cottage cheese.

45° F and provided that packages are cooled to 40° F or below in 4 to 6 hours. To facilitate obtaining these low temperatures, the jacket of the vat may be filled with chilled water during the draining and creaming operations. Also curd may be removed from the vat and placed in refrigerated storage to be creamed later in various mixing devices. It should be creamed with homogenized cream-milk mixture to 4.2–4.4 per cent butterfat. Salt is added to taste. Homogenized whole milk (or the mixture) may be added during mixing to produce desired consistency.

10. For whipped cream cottage cheese: (*a*) Curd is soaked in skim milk or homogenized whole milk overnight. (*b*) Cream of 32–36 per cent butterfat is whipped to a fairly stiff consistency. (*c*) Whipped cream is folded into curd to obtain a uniformly mixed product avoiding excessive agitation.

11. The product is packaged and returned to the cooler immediately. Temperature immediately after packaging should not be over 45° F, and the storage temperature should not be over 40° F.

Large Curd Type (Rennet): This method is essentially the same as for the small curd acid type except that:

1. When setting the milk, 1 ml rennet is added per 1,000 lb of skim milk. The rennet is diluted in thirty times its volume of cold water. Rennet is an enzyme that thickens the skim milk and strengthens the curd structure.

2. The curd is cut at a lower whey acidity, 0.45 to 0.5 per cent and ⅝-in. to ¾-in. curd knives are used. The finished product is less acid and curd particles are larger.

Home Manufacture: The basic procedure is the same as for commercial manufacture. A small amount of clean-flavored milk or skim milk may be allowed to sour naturally and used for a starter. Junket tablets (rennet) can be purchased at the local store. Any home making of cottage cheese is confined almost wholly to the farm where milk is produced.

Marketing: Because of its perishable nature, cottage cheese is sold locally near the point of manufacture. It is distributed principally from milk routes and through food stores. A good deal is shipped in milk cans or butter tubs to bakers, who use it for cooking.

Neufchatel Cheese. This cheese gets its name from a town in northwestern France, where it originated. The cheese is made from whole milk. The method is essentially the same as the rennet method for cottage cheese, but not quite so much acidity should be developed

in Neufchatel cheese. The yield is about the same as for cottage cheese. Neufchatel cheese is not made as extensively as cottage cheese. Pimentos, olives, or nuts are sometimes added to Neufchatel curd at the rate of an ounce to a pound of curd. This cheese has a very smooth, rich taste, and would pass for cream cheese, which is essentially the same as Neufchatel except that it is made out of milk testing 6 to 8 per cent butterfat. Neufchatel and cream cheese are usually put up in tinfoil-wrapped packages of from 3 to 6 oz.

Cheddar Cheese. This is the common American cheese that is for sale everywhere. Years ago most of this cheese was made on farms and only a little in factories, but the situation is entirely the reverse at present. Only a brief digest of the process of manufacture can be given here.

The first step in the manufacture of Cheddar cheese is the ripening of the milk to an acidity of 0.18 to 0.20 per cent so that the rennet extract will work properly. The ripening may be done by warming the milk to about 70° F and allowing it to stand, but usually ½ to 2 per cent starter is added to bring this about. Cheese color is usually added at a rate of 1 to 2 oz to 1,000 lbs of milk. The milk is then raised to a temperature of 86° F; the rennet extract is then added at the rate of 3 or 4 oz per 1,000 lb of milk. The rennet is first diluted in cold water, so that it can be thoroughly stirred in with the milk before any coagulation takes place.

Fig. 117. Cutting the curd for cheddar cheese. (Courtesy Kraft Foods Co.)

After the milk has coagulated quite firmly, which usually takes about 20 minutes, it is cut, by special knives, into $\frac{3}{8}$-in. cubes. The horizontal knife first cuts the curd into blankets; the vertical knife cuts it into strips $\frac{3}{8}$-in. square on the ends and as long as the vat; then the vertical knife is run the width of the vat to cut the strips into cubes. The acidity of the whey is now about 0.12 to 0.13 per cent. The heat is raised slowly to about 98° F and maintained until the cubes shrink to about half their original size. The acidity of the whey will then be about 0.17 to 0.20 per cent. The whey is then drawn off and the curds cheddared by stirring, after which they are allowed to mat. The matted curd is cut into blocks about 8 in. by 12 in. These blocks are turned at frequent intervals until the whey running from the curd has an acidity of from 0.7 to 0.9 per cent. The curd will tear like the white meat on the breast of a chicken. A piece of the curd held against a hot iron will string out $\frac{1}{2}$ to 1 in. long. The blocks are then milled, or cut by a machine known as a mill, into short strips $\frac{1}{2}$ to 1 in. square. These are allowed to remain, with frequent stirring, until the salt is added.

The pieces are salted at a rate of 2 lb per 100 lb of curd. The curd is allowed to cool to about 80° F before the salt is added. A special cheese salt, somewhat coarser than butter salt and requiring a trifle longer to dissolve, is used for this purpose. After the salt is

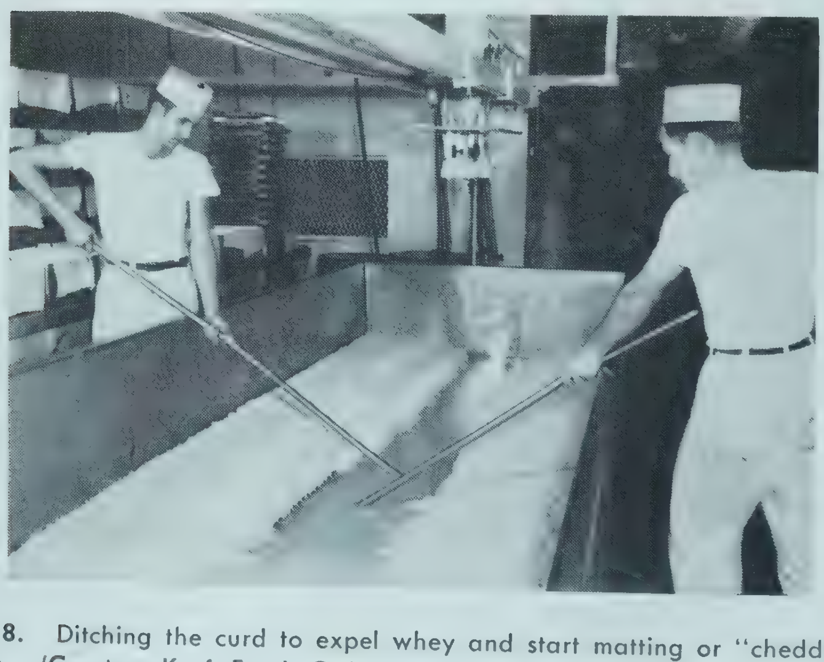

Fig. 118. Ditching the curd to expel whey and start matting or "cheddaring" process. (Courtesy Kraft Foods Co.)

Fig. 119. Cutting the cheddared curd. (Courtesy Kraft Foods Co.)

Fig. 120. Milling the curd. (Courtesy Kraft Foods Co.)

Fig. 121. Salting the curd. (Courtesy Kraft Foods Co.)

Fig. 122. Hooping the curd. Note square "hoops" instead of round ones formerly used. (Courtesy Kraft Foods Co.)

thoroughly dissolved, the curds are hooped. A number of styles of packages with special trade names are on the market. The hoops or forms are lined with cheesecloth or bandages; these then are filled with the curd and put in the press. In a few hours, the cheeses are taken from the press, dressed (the bandages straightened), and put back into the press for at least 24 hours. They are placed then in the curing room at 50° to 60° F and left there 2 to 6 months. The curing process mellows the cheese and develops its characteristic flavor. The cheeses must be turned frequently. In order to prevent mold and shrinkage, the cheese usually is paraffined after a few days. The yield of Cheddar cheese varies with the composition of the milk. Ten lb to 100 lb of milk is about the average.

On the farm, where the equipment is less elaborate, the cheese can be made by setting the milk in a pail, and the heating can be done by placing the pail in a large vessel of water on the stove. The curd can be cut with a butcher knife in the absence of a curd knife. The curd should not be allowed to "cheddar," or mat together, after the whey is drawn off, but should be put on a homemade drain rack and kept stirred. This stirring does away with milling; the salt is added to the stirred curd. A press can be made by catching a lever under a 2 in. $\times$ 4 in. joist spiked to the wall, placing the cheese hoop about 3 ft from the wall, and hanging a weight on the end of the lever 4 or 5 ft farther out.

Camembert Cheese. This is a soft rennet cheese made from cow's milk not exceeding 3.4 per cent butterfat test. The cheese was first made in 1891, at Camembert, France. It is now made to a considerable extent in the United States. Sweet milk is set with rennet, so that about 5 hours are required for the milk to thicken. The curd then is placed in cylindrical metal hoops, about 4½ in. in diameter and 4½ in. high, perforated with holes to facilitate draining. The draining process requires 2 days. The cheese then is salted on the outside and placed in a curing room having a temperature 53° to 59° F and a high humidity. The ripening must be done very carefully, as the flavor of the cheese depends on a proper balance in the development of mold, bacteria, and yeasts, which are the ripening agents. From 4 to 6 weeks normally are required before this variety of cheese is fit for the market.

Limburger Cheese. This is also a soft rennet cheese made from either whole or partly skimmed milk. Limburger cheese originated in Belgium and was marketed first in Limburg, whence it received

its name. It is made in large quantities in Wisconsin. The manufacture of this cheese differs from that of Camembert in that the milk is set at a higher temperature. Consequently coagulation takes place in about 40 minutes. The curd then is cut into small cubes and dipped into rectangular forms. It is allowed to drain without pressure. The cheese is turned frequently, and when drained enough to hold its shape, it is salted on the outside. Salt is rubbed on it every day until its surface becomes slippery. It then is ripened in a cellar at a temperature of 60° F. It is rubbed frequently during the ripening process, which takes 1 to 2 months. When ripe, the cheese is packaged. It has a very strong odor and taste.

Brick Cheese. The exact derivation of this name is not known. It may have been adopted because of the shape of the cheese, or because bricks are used for weighting down the press. This cheese is strictly an American product, being made in considerable quantities in the United States, especially in southern Wisconsin.

Sweet whole milk is set with rennet so that it will coagulate in 20 to 30 minutes. The curd then is cut into small cubes and heated in the whey to 110° to 120° F. After cooling, the curd is dipped into rectangular boxes on a draining table; a follower then is put on the curd and weighted down with bricks. After 24 hours of pressing, the cheese is salted and cured at 65° F. Curing requires 2 months.

Brick cheese is made in pieces measuring $10 \times 6 \times 3$ in. It has a strong, sweetish taste, and elastic texture, and contains many small, round eyes or holes.

Roquefort Cheese. This is a soft rennet cheese made from sheep's milk. It originated at Roquefort, France, and most of the genuine Roquefort is still made at that place. Imitations such as Blue cheese, are made in various countries, out of cow's milk. The great essential in making Roquefort is to develop a characteristic green mold throughout the interior of the cheese. When the separated curd is placed in the hoops, it is set in thin layers, and moldy bread crumbs are placed between each two layers. The cheese is cured in rooms held at 40° to 45° F. A free circulation of air is essential to the growth of the mold, and during the ripening of the cheese it is pierced by machinery with 20 to 60 small needles, in order to permit the free access of air. A minimum of 30 to 40 days is required for ripening. When ready for market, the cheese weighs 4½ to 5 lb.

Emmental or Domestic Swiss. This cheese originated in Canton Bern, Valley of Emmental, Switzerland, in the middle of the fifteenth

century. It now is made in almost every civilized country. Whole milk is placed in a steam-heated copper kettle having a capacity of 300 gal. The milk is set to coagulate in 30 to 40 minutes. The curd is cut very fine, with a tool known as a harp, and then is heated in the whey until it will no longer stick together. This may require a temperature of 130° F for an hour. The curd is stirred constantly during the heating process. A bag then is run under the curd and the whole mass lifted out into a large hoop for pressing. After pressing, the cheese is salted in a tank of brine, the brine being strong enough to float an egg. This process takes from 1 to 4 days. The cheese is cured in cellars ranging in temperature from 55° to 65° F. A period of 3 to 6 months is required to ripen it. When ripe, the cheese is hard, like a Cheddar, but is characterized by holes, or eyes, which develop to about the size of a cent and are 1 to 3 in. apart. This cheese has a somewhat mild, sweetish flavor.

Process Cheese. This type of cheese is defined as "the clean, sound, pasteurized product made by comminuting and blending, with the aid of heat and water, with or without the addition of salt, one or more lots of cheese into a homogeneous, plastic mass." Process cheese possesses excellent keeping qualities. It is convenient to merchandise, uniform in quality, economical to use in the home be-

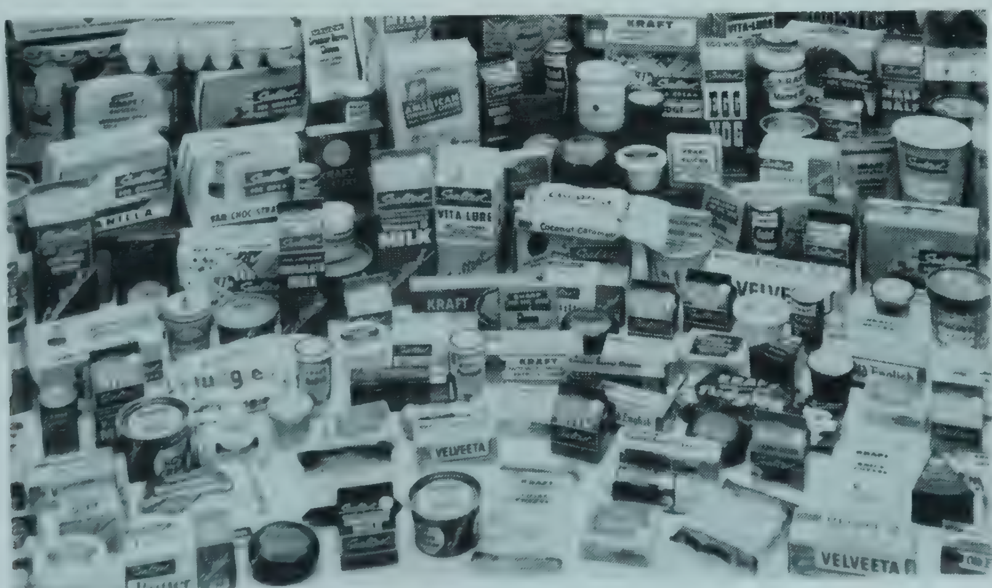

Fig. 123. Different kinds of packaged cheese and other dairy products. (Courtesy Kraft Foods Co.)

cause of the absence of rind, and safe because it is pasteurized. The method of manufacture is somewhat complicated and requires considerable experience and special equipment.

Recent Developments in Packaging Cheese. Obviously it is desirable that hard cheese be packaged at the factory rather than cut and wrapped in the retail store. Cheese so cut may not always be handled in a sanitary manner, and there is waste from drying and from the rind which must be thrown away. Processed cheeses are packaged in containers of a size suitable for home use. Ordinary American or Cheddar cheese also is being packaged in retail packages varying in size and shape. These improvements in packaging make it possible to sell better cheese more conveniently, which results in increased use of cheese. In fact, cheese consumption in the United States nearly doubled from 4.5 lb per capita in the 1925–1929 period to 8 lb in 1956.

QUESTIONS

1. What are the more common varieties of cheese?
2. Name two fundamentals involved in cheese making.
3. What are the essential characteristics of cottage cheese?
4. Cottage cheese consists principally of what milk constituent?
5. What is the butterfat standard for creamed cottage cheese?
6. What are the essential differences between the "short set" and the "long set" methods of making cottage cheese?
7. What is the function of starters in cheese making?
8. What is meant by "cutting the curd"?
9. What is the object of heating the curds in the whey?
10. What is the object of washing the curd?
11. Why is it important that the last wash water be ice cold?
12. What is whipped cream cottage cheese?
13. What are the differences between the small and large curd types of cottage cheese?
14. How could you make cottage cheese in the home?
15. Why is it important to use extreme cleanliness in the manufacture of cottage cheese?
16. Why would you say it is important to code the cottage cheese package as to the date of manufacture?
17. What is Neufchatel cheese?
18. List in outline form the steps taken in the manufacture of Cheddar cheese.
19. How would you make Cheddar cheese on the farm?

20. What is the nature of Camembert cheese?
21. What are the essential steps in the manufacture of Camembert cheese?
22. What is the nature of Limburger cheese?
23. What are the essential steps in the manufacture of Limburger cheese?
24. What are the characteristics of brick cheese?
25. Outline the essential steps in the manufacture of Roquefort cheese.
26. What are the characteristics of Swiss cheese?
27. What is meant by process cheese and how is it prepared?
28. How do today's cheese packages differ from those of several years ago?

PROBLEMS

1. If 12 per cent T.S. milk yields 10 lb of Cheddar cheese per 100 lb of milk, what would 14 per cent T.S. milk yield? *Ans.* 11.66 lb

2. Which would yield the most gross profit, and how much: selling the butterfat in 4 per cent milk at 50 cents a lb in the form of 30 per cent cream, and selling the skim milk in cottage cheese (16 lb per cwt) at 20 cents a lb, or making Neufchatel cheese and selling it for 40 cents a lb? (18 lb cheese to cwt.) *Ans.* \$2.43 in favor of Neufchatel

3. Neufchatel cheese from 4 per cent milk yielded 20 lb cheese per cwt. Whey tested 0.4 per cent butterfat. What was per cent of butterfat in cheese? *Ans.* 18.4 per cent butterfat

4. Cottage cheese from skim milk, 9.6 per cent T.S., yielded 16 lb per cwt. What is the per cent moisture in the cheese? Disregard solids in whey. If cream is added at rate of 1 lb of 40 per cent cream to 10 lb of curd, what will be the butterfat test of cheese?
Ans. (*a*) 40 per cent water, (*b*) 3.63 per cent butterfat

5. With 4 per cent milk at \$4 per cwt and 30 per cent cream at 50 cents per lb for butterfat, what will it cost to make enough 7 per cent cream for 20 lb of cream cheese? (20 lb of cheese to cwt.) *Ans.* \$5.25

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CHAPTER **21**

Miscellaneous Dairy Products

Cream. Most of the cream sold to the consumer is of two types, "coffee cream," testing about 20 per cent butterfat, and "whipping cream," testing 30 to 40 per cent. Cream sales appear to be levelling off at about 70 to 75 per cent of the sales prior to World War II. Sales are about 47 lb of milk equivalent per capita. Diet consciousness has resulted in less use of cream, notably in coffee, and by many cream must be considered a luxury.

Housewives sometimes are vexed because cream will not whip, and this causes considerable trouble to the milk dealer. Some of the principal factors which determine the whipping quality of cream are butterfat content, temperature, aging time, fullness of the whipping bowl, and the type of whipper used. Cream should be stored in the home at 50° F or below and should be kept at this temperature when whipped. The whipper and whipping bowl should be chilled, especially in hot weather, to keep the cream cold enough for satisfactory whipping. If the cream is 60° F or above, it is likely to churn when one attempts to whip it.

Whipping cream is now commonly dispensed in pressurized gas charged cans. The whipped cream is extruded by simply pressing a valve at the top of the can.

In many states a product commonly known as "half and half" is sold. This product is an homogenized mixture of milk and cream, testing 10 to 12 per cent butterfat. It may be used in coffee and is especially adapted for use on breakfast cereals.

Skim Milk. Sales of skim milk in its natural form and of that reinforced with milk solids and vitamins have increased markedly in recent years, owing to the emphasis consumers are placing on their waistlines. It may be said to be a major product of the fluid milk business. Skim milk frequently is sold under the name of non-fat milk.

Chocolate Milk or Drink. Chocolate milk is sweetened whole milk flavored with chocolate. Chocolate drink is the same thing, except that the product contains only 1 to 2 per cent butterfat. Much more chocolate drink than chocolate milk is sold. Chocolate milk shakes have long been a popular drink at the soda fountain. Chocolate milk and drink are now put out in bottles by milk dealers, and are sold in schools in some areas, at soft drink stands, and retailed to considerable extent to the home. They are most popular in the summer as a beverage, and because they are used by many who will not drink milk, they probably do not affect the sale of milk as such.

Milk dealers prefer to sell a product uniform in color from top to bottom. The cream layer can be prevented by high temperature pasteurization of the milk, or better still, by homogenization of the product. Of course, a lighter-colored cream layer does not form when skim milk is substituted for whole milk. A sediment layer at the bottom of the bottle can be prevented by thickening the product to a point at which the cocoa specks will not settle out. A number of products, such as sodium alginate, vegetable gums, Irish moss, or corn starch, can be used for this purpose. As little as 1 oz of the former will prevent sedimentation in approximately 4 gal of chocolate milk. Specially prepared chocolate powders and chocolate syrups are being sold, which make a product that will not develop a sediment layer. It is these products that most milk companies use.

Starter. A starter may be defined as milk or skim milk containing a clean acid flavor. This flavor is the result of adding a pure culture of lactic acid forming bacteria to pasteurized milk or skim milk and allowing the acid to develop at the proper temperature. There are a number of companies that supply the concentrated cultures in powdered or liquid form.

These cultures are used to prepare a small amount of starter, known as the "mother." It, in turn, is added to a larger lot of milk to make the "main" or "bulk" starter. In brief, the steps in preparing the mother starter are as follows:

1. Use milk of best possible quality.
2. Be sure all utensils used are sterilized.
3. Pasteurize the milk at 180° to 190° F for an hour.
4. Cool to 70° to 72° F.
5. Add the pure culture and shake to mix well.
6. Incubate at 70° to 72° F for 15 to 16 hours or until a smooth curd, testing about 0.85 per cent acid has formed.
7. Cool to 40° F and hold for use. More mother starter is made by transferring 1 to 1.5 per cent of the starter to more pasteurized milk and so on and on. With proper care, it will not be necessary to purchase another pure culture for a long time.

Fig. 124. Culture bottle for mother starter. (Courtesy Meyer-Blanke Co.)

Fig. 125. Processing tank for pasteurizing, cooling, and incubating starter. (Courtesy Meyer-Blanke Co.)

Commercial Sour Cream. This product is a heavy-bodied ripened cream of high acidity, clean flavor, and smooth texture. It is very popular with the Slavic races, Germans, and Bohemians. The cream used for the product should be standardized to at least 18 per cent butterfat, pasteurized at 180° F for 10 to 30 minutes, and homogenized or viscolized with from 3 to 10 per cent starter, depending upon the time available. About 0.6 per cent acid should develop. It is packaged with as little agitation as possible, cooled to 40° F or lower, and aged for 12 to 24 hours before marketing. It is necessary to have this product smooth, very thick (semisolid), and free from whey. Some condensed skim milk or powdered skim milk, and

sometimes a small amount of stabilizer may be added to secure a very thick consistency.

Buttermilk. Buttermilk is consumed in large quantities as a beverage. The casein in buttermilk is in a form which makes it especially easy to digest. The drink has a beneficial effect on the digestive processes, in that it prevents certain undesirable intestinal putrefactions. Since the bulk of the natural buttermilk is produced far away from the large eastern centers of population, cultured buttermilk is made to meet the demand. Most of the cultured buttermilk on the market is merely a good starter, such as is used for ripening cream. At times, the skim milk from which it is made is standardized with whole milk or cream so as to contain 0.5 to 2 per cent butterfat. This makes a more palatable product than skim milk alone. A defect which occasionally occurs in cultured buttermilk is "wheying off," that is, the curd settles in the bottle and a clear layer of whey can be seen. The defect can be eliminated by developing a satisfactory amount of acidity, by preventing contamination of the starter culture, and by agitating the product as little as possible after coagulation has occurred. Ordinarily the common lactic type of culture is used to make commercial buttermilk.

The method of making commercial buttermilk is as follows: fresh skim milk is pasteurized at 180° F and held for 30 minutes, preferably in a stainless steel vat. The skim milk then is cooled to 68° or 70° F, and about 1 per cent or more starter culture is added. After standing about 14 hours the skim milk will coagulate and develop from 0.7 to 0.8 per cent acidity. The curd then is broken by slow-speed agitation and the product cooled by circulating chilled water through the jacket of the vat. The buttermilk is bottled and kept cold until delivered to the consumer.

Buttermilk containing small flakes or granules of butter is very popular. There are a number of ways to add these granules to the buttermilk. Some manufacturers add rich cream to the buttermilk, along with standard butter color, and churn the mixture until the butter granules form. A more common procedure is to churn the cream separately until the granules are formed, and then combine the buttermilk and butter granules. The flakes also have been obtained by spraying melted butter into the stirred cold buttermilk. The melted butterfat droplets solidify when they enter the buttermilk.

Buttermilk can be made in a small way in the home, with buttermilk tablets purchased at the drug store. The directions accompanying the package should be followed.

Concentrated Milks. As the name implies, concentrated milk is whole milk from which a portion of the water has been removed by boiling under vacuum in special equipment. The process of concentration under vacuum was discovered by Gail Borden in 1856. The following are the various types of concentrated fluid dairy products.

Plain Condensed Milk. This is whole milk from which a portion of water is removed. It contains 10–12 per cent butterfat and 36–38 per cent total solids. This product is handled in bulk, cans, or tanks and is used in manufacturing baked goods, candy, ice cream, etc.

Plain Condensed Skim Milk. Skim milk from which a portion of the water is removed contains about 30 per cent milk solids. This product is handled and used much the same as condensed whole milk.

Superheated Condensed Whole Milk or Skim Milk. This is the product which results when whole or skim milk is condensed to a high concentration of solids, about 3 or 4 to 1. Then, while in the vacuum pan, it is subjected to a high temperature (about 185°–190° F), generally with flowing steam injection. The product is handled in cans or tanks and used for manufacturing.

Condensed Sweet-cream Buttermilk. This product results when a portion of the water from sweet-cream buttermilk is removed. It is a bulk product and is used in manufacturing.

Condensed Buttermilk. Condensed buttermilk is obtained when a portion of the water is removed from sour buttermilk. It may be used in baking and for animal feed.

Semisolid Buttermilk. This is the product which results when a relatively large proportion of the water is removed from sour-cream buttermilk so that the concentration of solids is about 5 to 1. This product is packed in bulk containers of various sizes and used in animal feeding.

Sweetened Condensed Whole Milk or Skim Milk. The addition of sufficient sugar to plain condensed whole or skim milk to insure preservation of the concentrated milk results in a product known as "sweetened condensed whole milk" or "sweetened condensed skim milk." Whole milk contains about 8 per cent butterfat and 28 per cent total milk solids; skim milk contains about 25 per cent milk solids. Both contain 42 per cent sugar. The product is generally packed in barrels or drums and used for manufacturing food products. Some of the sweetened whole milk is packed in small tin cans for use in the home.

Evaporated Milk. The term evaporated milk is applied to the product which, after concentration to the desired ratio (about 2.1 to 1), is placed in hermetically sealed tins and subjected to high temperatures to insure sterilization. Federal law requires 7.9 per cent butterfat and 25.9 total milk solids. Evaporated milk finds wide use in the home for cooking purposes and for infant feeding. Doctors frequently recommend it because of its uniform composition, sterility, convenience, and digestibility, which are a result of the homogenization and heat treatments used in its manufacture.

METHOD OF MANUFACTURE. Milk, upon arrival at the condensery, is pumped into large storage tanks to be standardized. Thence it is drawn into large stainless steel kettles or tanks, or hot wells as they are called, where it is fore-warmed (in the case of sweetened milk to 180°–200° F and of evaporated milk to 130°–150° F). About 17 per cent sugar is added in the hot well to the milk that is to be made into sweetened condensed, and the milk is heated higher to dissolve

Fig. 126. Vacuum pan and condenser for making condensed and evaporated milk.

this sugar. To avoid evaporation at 212°–214° F, the milk is drawn into a vacuum pan, where a 25- to 26-in. vacuum is maintained, so that the milk boils at about 130° F. The pan is a large kettle with steam jacket at the bottom and steam coils around the inside. At the top of the pan is the condenser, where the vapor arising from the milk is condensed with a spray of cold water. A steady stream of milk is drawn into the vacuum pan, until specific gravity tests of the product show that the milk is about ready to draw and the pan is loaded to its capacity with the condensed product. In large operations, the pan is operated continuously, a steady flow of milk entering and a steady flow of finished product being pumped from the pan.

COOLING AND PACKAGING CONDENSED MILKS. After condensing reaches the proper point, the product is cooled. The system used varies materially in the case of sweetened and unsweetened condensed milk. Unsweetened condensed milk may be cooled in coil vats, or over surface coolers. Sweetened condensed milk must be cooled quickly and with some agitation. If agitation is used it must be slow, and conducted in such a manner as to prevent the in-

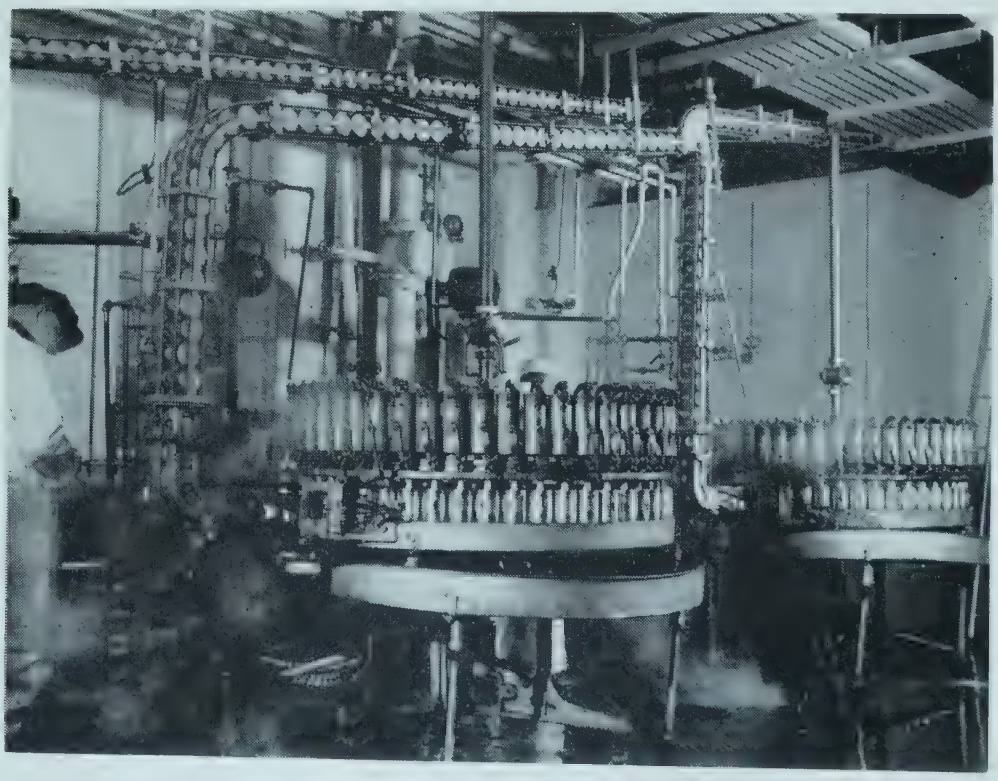


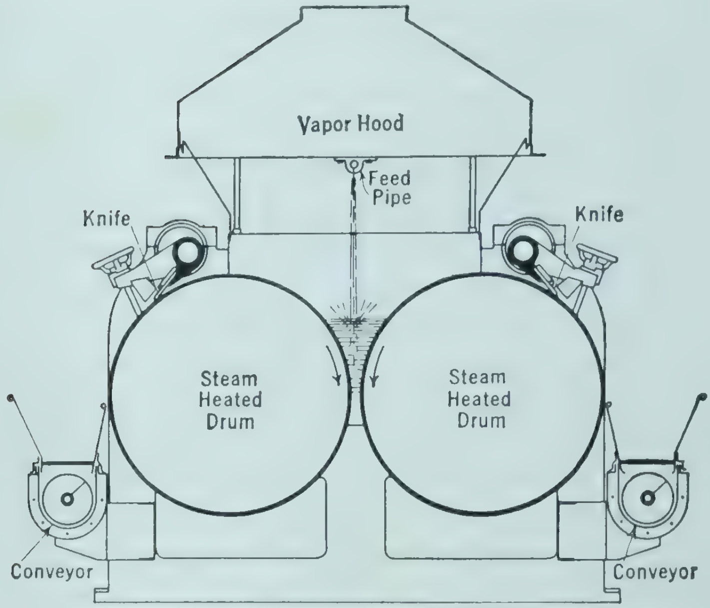
Fig. 127. Filling and sealing cans of evaporated milk. (Courtesy The Borden Co.)

corporation of air in the finished condensed milk. Owing to the high lactose content of sweetened condensed milk and the danger of the sugar crystallizing from the condensed, extreme care must be taken. It is common practice to "seed" the product by adding a small amount of milk sugar to prevent a "sandy" product, as it is called. The added grains of milk sugar serve as nuclei to attract small grains of milk sugar in the product. Thus larger, more readily soluble crystals are formed.

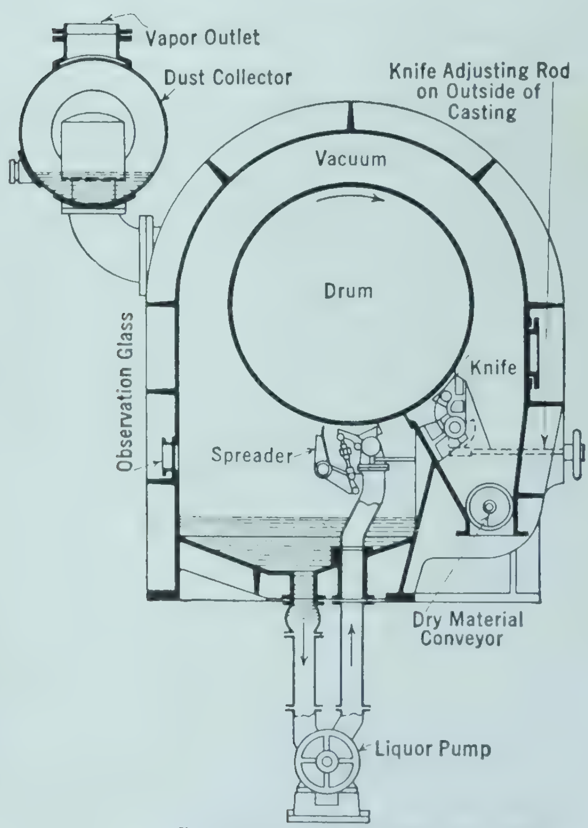
After condensing and cooling, the condensed milk is placed in the packages in which it is marketed. Sweetened condensed milk or skim milk is generally packed in barrels, except that some whole milk is packed in small cans for use in the home. If kept reasonably cool, the sugar acts as a preservative and the product keeps for several months. Plain whole or skim condensed milk is generally handled in 40-qt milk cans. Evaporated milk is homogenized, cooled, placed in tins holding 14.5 or 6 oz, and sterilized. After sterilization, the canned milk is placed in shaking machines to break the coagulated casein. The finished evaporated milk generally is held for a period at the factory to permit any defects to develop which may be due to bacterial fermentation or faulty methods of handling the product.

Fresh Concentrated Milk. This is a 3 to 1 product, 10 to 12 per cent butterfat, processed and handled in bottles for home use like regular whole milk. The housewife may use this milk without dilution in cooking or on breakfast cereals or reconstitute by adding water to make normal 3.5 to 4 per cent butterfat milk for drinking or other purposes. Interest in such a product has been aroused in several areas because of the possible economy involved. It is reasoned that milk could be concentrated in the country, it could be shipped to the city for processing, bottling, and delivery, and savings would result by transporting two-thirds less product from the country and on delivery routes in the city. Thus far these savings, partly offset by the cost of concentrating, have not seemed to be enough, possibly 2 cents per quart in terms of fluid milk, to greatly interest the consumer. The theory is sound and the idea may develop further.

Sterile Concentrated Milk. This takes the concentrated milk idea one step further. Obviously if a canned concentrated milk could become a store shelf item, kept without refrigeration like evaporated milk, and still have the flavor and color of fresh milk instead of the cooked flavor and caramel color of evaporated milk, there would be a big demand for it. For years such a product has been the goal of



(*a*) The atmospheric dryer.



Courtesy of the Buffalo Foundry Co.

(*b*) The vacuum drum dryer.

Fig. 128. Drum-type milk dryers. (A. W. Farrall: Dairy Engineering, John Wiley, 1953.)

many research workers. More recently considerable progress has been made at the University of Wisconsin (*Research Bull. 204*) and the day may not be too far in the future when sterile concentrated milk will be on the general market.

Dry Milk. It is reported that dry milk was first made in England in 1855. Its manufacture in America dates back to about 1900. There are several patented processes for drying milk. Either the hot-roll, or film drying method, or the spray principle is employed.

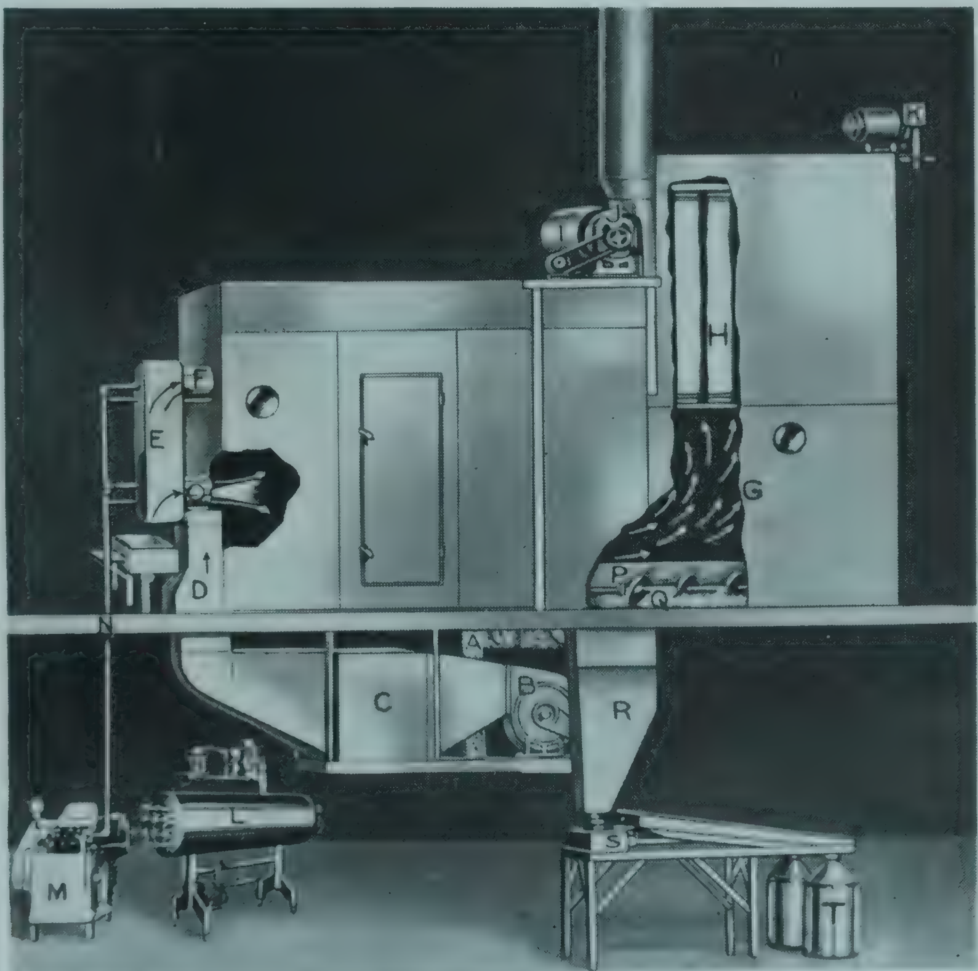


Fig. 129. How milk is spray dried. Condensed milk is preheated, L connected to homogenizer H which pumps milk to spray jets F and O, hence into the drying chamber with heated air from duct D. The dried product Q drops to the floor of the drying chamber and is pushed through chute R to shaker S and into containers T. Duct collectors H collect any powder tending to escape through outlet flue with heated air.

In the roller process, hollow, steam-heated rolls are so arranged that they pick up a film of milk, either by barely dipping into a tank of milk underneath the roller, or by having the milk sprayed onto the roller. When the roller, after taking on its film of milk, has made about three-quarters of a revolution, it is ready to take on more milk. The milk is dried in a thin film. Scrapers are so arranged that they scrape the dried milk from the roller at this point. The dry milk is placed in a dry kiln to complete the drying and is then ground to a powder and packed in tins or barrels.

In the spray process, the milk is partly condensed and is then sprayed in a mist to the top of a chamber of heated air. The air takes up the moisture and is blown out; the powdered milk falls to the bottom of the chamber.

The following are the types of dry milk:

Dry Whole Milk. Dry whole milk made by the spray process must contain at least 26 per cent butterfat and not over 5 per cent moisture. This product is not made very extensively as yet, since the commercial product does not keep well and no practical method of making a product that reconstitutes easily has been developed.

Dry Skim Milk. (Nonfat Dry Milk.) This product contains not more than 5 per cent moisture. It has wide usage, and production has increased from 83 million lb per year in the 1925–1929 period to 1½ billion lb in 1956. Spray process powder now is treated so it dissolves readily in cold water and a considerable quantity is sold in retail packages. In bulk packages, barrels and drums, it is sold for use in the food industries, notably baking, candy, ice cream, and meat processing. Some roller-process powder also is used in the food industry, and much of it is used for animal feed.

Dry Buttermilk. Considerable sweet and sour buttermilk is roller dried for food processing and for animal feed. Some sweet-cream buttermilk is spray dried.

Miscellaneous. Whey, cream, and ice cream mix have been dried, but extensive uses for these products have not yet been developed.

Malted Milk. Malted milk is the product made by combining whole milk with the liquid separated from a mass of ground barley malt and wheat flour. The resulting product must contain not less than 7.5 per cent butterfat and not more than 3.5 per cent moisture.

Wheat flour and barley malt are mixed to form a mash. This mash is held at a temperature that permits the conversion of insoluble starch into digestible sugars. The extract derived from the mash is

then mixed with milk and the mixture is dried to a powder in vacuum.

Malted milk is very easily digested, and hence it is an excellent food for infants and invalids. It possesses excellent keeping qualities that make it of special value for use in warm countries where the dairy industry has not yet been developed. Usually it is mixed with fluid milk and ice cream as a soda fountain drink.

Dried Casein. Casein is made out of surplus skim milk. The process, in brief, consists of warming the milk to 86° F and adding enough dilute sulfuric or hydrochloric acid to separate the curd and give a clear whey. The whey is drawn off and the curd is washed in cold water to remove the acid and to cause the particles of curd to unite. The fresh curd is then ground up and spread out on wire trays. These trays are placed in a drying chamber at about 115° F for about 24 hours. The curd also may be dried by a continuous process. The product then is put in burlap bags and sent to refining jobbers who prepare it for use as imitation ivory, glues, paints, and scores of other articles.

By-Products of Whey. A large quantity of whey is available as a by-product of cheese making or casein manufacture. The whey contains milk sugar, albumin, and most of the minerals of milk, hence it

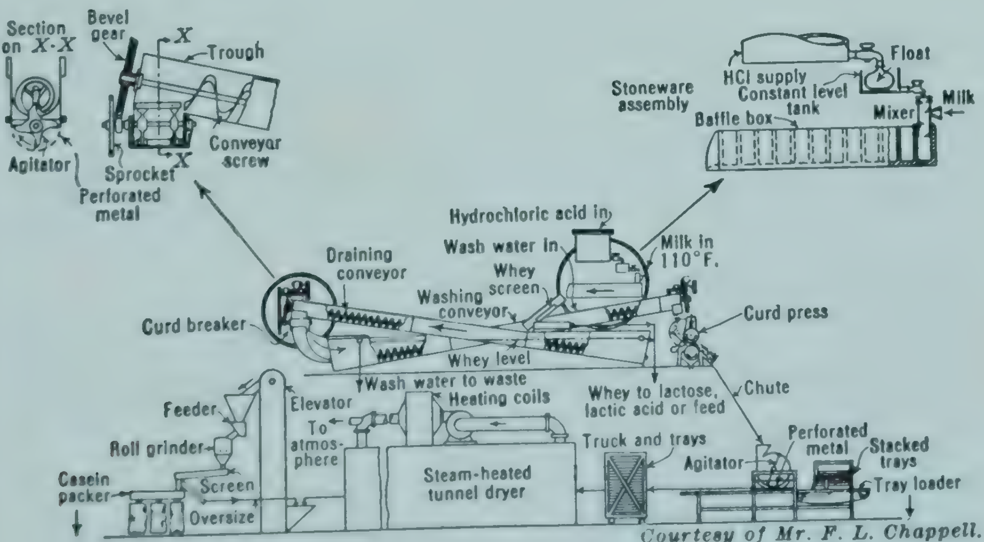


Fig. 130. The continuous casein machine. (A. W. Farrall: Dairy Engineering, John Wiley, 1953.)

should not be thrown away. Milk sugar is made from whey in districts where cheese is manufactured. The whey first is heated to the boiling point to precipitate the albumin. After treatment with calcium hydroxide, it is evaporated in a vacuum pan to a thick syrup. It then is run into shallow containers and cooled, which causes it to crystallize into a yellow sugar. The crude product goes through an extensive refining process and finally appears as a white, powdered material. It is used in the drug industry and for modifying milk for infant feeding.

Condensed and powdered whey is used in poultry feeds, principally because of its high vitamin G (riboflavin) content. The high lactose content is also valuable in preventing coccidiosis in poultry flocks. The manufacture of milk sugar (lactose) from whey already has been described. Whey, because of its cheapness, is used in the production of lactic acid from the lactose in it. Tanners and producers of acid beverages and sherbets use most of the lactic acid produced. Lactic acid also is used in making phenolic resins. The conversion of lactose to alcohol is simple, and the alcohol can be made into vinegar. Doubtless other profitable means of utilizing whey will be developed in the future.

QUESTIONS

1. What is the difference between "coffee cream" and "whipping cream"?
2. What are the principal factors determining the whipping quality of cream?
3. What is the latest development in the dispensing of cream for whipping?
4. Why is skimmed milk becoming more popular as a beverage?
5. What is the difference between chocolate milk and chocolate drink?
6. How is the sediment layer in the bottom of a chocolate drink prevented?
7. What is a starter?
8. What is the difference between "mother" starter and "main" or "bulk" starter?
9. Mention some of the precautions necessary in preparing and handling starters.
10. What are some of the uses of starters?
11. Outline step by step the processing of commercial sour cream.
12. Why is buttermilk a healthful beverage?
13. What is "wheying off" in buttermilk and how may it be prevented?
14. Outline step by step the buttermilk making process.

15. How is buttermilk containing butter granules manufactured?
16. When and by whom was the process of concentrating milk discovered?
17. What is the difference between plain condensed whole milk and plain condensed skim milk?
18. What is meant by superheating?
19. What are the uses of concentrated milk other than evaporated milk?
20. What is meant by "sandiness" and how is it prevented?
21. What are the packages used for concentrated milk and for evaporated milk?
22. Why does sweetened condensed milk and evaporated milk keep for a long time at room temperature?
23. What are the two general methods of drying milk?
24. How do dry whole milk and dry skim milk differ?
25. Why is dry whole milk not in more common use?
26. What factor has lead to a considerable increase in the use of dry skimmed milk in retail packages?
27. Define malted milk.
28. Outline the steps in the manufacture of malted milk.
29. How is dried casein manufactured?
30. What are some of the major uses of dried casein?
31. How is milk sugar manufactured?
32. What are the uses of milk sugar?
33. Why is dried whey a valuable animal feed product?
34. What other commercial products are made from whey?

PROBLEMS

1. Find the equivalent of 1,000 lb of 3.5 per cent milk, in lb of water and whole-milk powder containing 26 per cent butterfat.
Ans. 865.39 lb water; 134.61 lb powder

2. Find the equivalent of 5,000 lb of 3.5 per cent milk, in terms of skim-milk powder used at rate of 9 lb of powder and 91 lb of water (figure test 0) and unsalted butter containing 84 per cent butterfat.
Ans. 208.33 lb butter; 431.25 lb skim-milk powder

3. How much unsalted butter, 84 per cent butterfat, and skim-milk powder and water must be mixed to make 100 lb of 3.5 per cent milk? (Figure skim milk 9.25 per cent solids.)
Ans. 4.16 butter, 8.86 lb powder, 86.98 lb water

4. You have 20 lb of 84 per cent unsalted butter on hand, and plenty of skim-milk powder and water. How many pounds of 30 per cent cream can you make up?
Ans. 56 lb 30 per cent cream

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CHAPTER **22**

The Food Value of Milk and Milk Products

Food Requirements. The main requirements to sustain the human body are water, protein, carbohydrates, fat, minerals, and vitamins.

The human body consists of about 60 per cent water. All food consumed by man and animal contains water. Milk consists of a relatively high percentage of water, but so do many vegetables and fruits. Some items such as tomatoes, turnips, lettuce, melons, and peaches contain more water than milk contains.

NUTRITIONAL SIGNIFICANCE OF MILK CONSTITUENTS. *Milk Protein.* Man requires a readily available supply of proteins to promote growth of muscular and other body tissues. Proteins are made up of amino acids. These amino acids of the food proteins are often designated as "building blocks," from which the body fabricates its own special protein tissues. The importance of adequate protein in the diet cannot be overemphasized; this importance is reflected in the table of dietary-allowances. All proteins are not of equal nutritional value, because some do not contain balanced amounts of all of the essential amino acids. Milk contains superior proteins, not only because they contain all essential amino acids, but also because milk contains extra amounts of those often low in plant proteins. Thus milk supplements the protein of other foods and makes them more adequate. For this reason the use of milk in breadmaking is a sound nutritional practice. In general, the proteins in dairy products are an economical source of high-quality protein.

Fat and Carbohydrate of Milk. Carbohydrates and fats are im-

Fig. 131. Milk made the difference. (Courtesy National Dairy Council.)

portant nutritionally, primarily as sources of energy. Energy is measured in calories. These food elements provide about 89 per cent of the calorie intake in the dietary of this country. Fat yields about 9 cal per g, whereas carbohydrate and protein each yield about 4 cal per g. A calorie is the amount of heat required to raise the temperature of a pound of water 4° F. One quart of average milk furnishes 670 calories. The intake of fat and carbohydrate should be sufficient to provide the energy requirements of the body so that protein may be used for its primary function, that of supplying tissue-building material. In ordinary diets in the United States, fat provides more than 40 per cent of the total calories.

The carbohydrate of milk is lactose or milk sugar. Lactose consists of equal parts of glucose and galactose. It is digested and assimilated somewhat less rapidly than most other sugars. According to several investigators, lactose may be carried into the lower intestinal tract where the mild acidity which develops from it appears to aid in calcium assimilation.

Minerals. A balanced diet that will sustain man during his growth and development must contain more than a dozen minerals. Liberal use of milk and milk products will insure an adequate intake of calcium and will contribute substantial quantities of phosphorus, potassium, sodium, chlorine, magnesium, and sulfur. Trace minerals such as zinc, copper, and cobalt also are found in milk.

Calcium. Of the minerals essential for the growth and maintenance of the healthy human, calcium is one of those needed in large amounts. It is the main constituent of the bones and teeth. It is also an essential element in all living cells and it plays a vital part in regulating processes involving cellular activity. The need for calcium is a continuing one, regardless of age. Calcium is stored in the body structures and is used as needed if the intake is adequate. Severe skeletal depletion may occur before the effects of insufficient calcium are detectable. Surveys have demonstrated that bodily disturbances due to lack of calcium are associated generally with low consumption of dairy products.

Phosphorus. Phosphorus also is needed in large amounts. Even more phosphorus is required than calcium. It is essential in building teeth, bones, and soft tissues and in maintaining many of the body processes. Milk and dairy products are excellent sources of phosphorus. The phosphorus in milk is accompanied by other nutrients with which it is used in the body.

Vitamins. The average values for the vitamin content of milk and milk products given in Table 35 show that dairy products are an important source of these nutrients.

Vitamin A. The total vitamin A content of dairy products is the sum of the actual vitamin which is colorless, and the carotene, the precursor of vitamin A, which is yellow. Carotene contributes largely to the yellow color of butter. Both carotene and Vitamin A are fat soluble and are found in dairy products in the butterfat portion. Vitamin A is essential for growth and for maintaining the surface layers of skin in a healthy condition.

Vitamin D. Much of the fluid milk now available to consumers is fortified with vitamin D and is so labeled. Vitamin D assists in the utilization of calcium and phosphorus, thus playing a vital role in the formation and maintenance of bones.

The following are present in the nonfat portion of milk and are a part of Vitamin B complex: *Thiamine* is a water-soluble vitamin that has been shown to be essential for growth. It prevents the nerve disease known as beriberi, and is an integral part of an enzyme

system concerned with carbohydrate metabolism. Like thiamine, *riboflavin* is water-soluble and is also essential for growth. Its presence in the diet is beneficial in the prevention of characteristic lesions of the mouth, skin, and eyes. It also appears as part of an enzyme system necessary for metabolism. *Niacin* is one of the factors which prevents the dietary disease known as pellagra. It also facilitates enzymatic reactions concerned with metabolism. Although niacin content in milk is low, the niacin equivalent value is high, due to the presence of tryptophan from which niacin is formed in the body. *Ascorbic acid* is the vitamin required to prevent or cure scurvy. It functions, too, in some way in the enzyme reactions in the body. Milk contains about 14 mg of ascorbic acid per qt.

Dairy Products as a Source of Food Requirements. The Food and Nutrition Board of the National Research Council in Washington, D.C., has recommended daily dietary allowances for men, women, and children of varying ages. These allowances are shown in Table 35. The literature contains the composition of various dairy products and the amounts of nutrients and energy furnished by an average serving of these products. To give an idea of the value of dairy products and their components, Table 35 has been prepared from data selected from a "Food Value of Dairy Products" compilation prepared by the Research Laboratories of the National Dairy Products Corporation. By studying this table it will be seen that dairy products go a long way in supplying the nutritional needs of the body. The table also makes clear which products are particularly high in certain components. It will be noted that dairy products supply a high ratio of nutrients to calories, which makes dairy products particularly useful in a reducing diet. It will be noted that a ⅓-cup serving of cottage cheese supplies nearly ⅙ of the protein requirement, whereas a glass of milk supplies ⅓ of the calcium requirement. The table also indicates at a glance that dairy products containing butterfat are good sources of vitamin A. It also can be seen that other vitamins are present in considerable quantity in the various products. In summary, therefore, it may be said that dairy products contribute generously to the nutrient requirements.

There are additional vitamins in the so-called vitamin B complex to be found in dairy products, but there is insufficient knowledge at present to establish recommended daily dietary allowances for these vitamins. There follows a description of these substances of the vitamin B complex, and the extent to which they are found in dairy products is shown in Table 36.

TABLE 35. FOOD AND NUTRITION BOARD, NATIONAL RESEARCH COUNCIL, RECOMMENDED DAILY DIETARY ALLOWANCES—1958

	Age, years	Weight, lb	Height, in.	Calories	Protein, g	Calcium, g	Iron, mg	Vit.A. I.U.	Thiamine, mg	Riboflavin, mg	Niacin, mg	Ascorbic Acid, mg	Vitamin D I.U.
Man	45	154	69	3000	70	0.8	10	5000	1.5	1.8	21	75	
Child	7–9	60	51	2100	60	1.0	10	3500	1.1	1.5	14	60	400
Nutrient Materials Supplied By Average Servings of Various Dairy Products													
Whole milk, 3.7% butterfat, 1 glass 8 fl oz				156	7.9	290		353	0.01	0.41	0.34		4.1 plain 100 Vit.D
Chocolate drink, 2% butterfat, 1 glass, 8 fl oz				185	7.4	264		202	0.89	0.43	0.35		2
Buttermilk, 0.5% butterfat, 8 fl oz				88	7.9	278		50	0.10	0.43	0.35		0
Evaporated milk, 7.9% butterfat, ½ cup				173	8.6	315		418	0.07	0.45	0.23		4 unless fortified
Whipping cream, 35% butterfat, 1 tbsp				51	0.3	12		221	trace	0.02	0.01		2
Butter, 1 pat or 2 tsp				73	0.1	2		342	0	0	0		3
Vanilla ice cream, 12% butterfat, ⅙ qt				187	3.6	128		454	0.03	0.17	0.09		5
Creamed cottage cheese, 4% butterfat, ⅓ cup				81	11.6	74		125	0.02	0.20	0.01		
American Cheddar cheese, 32.3% butterfat, 1 oz				111	6.7	247		385	0.01	0.14	0.07		4

The human need for *biotin* has been established although its specialized function has not yet been clearly demonstrated. *Pantothenic Acid* is essential in the maintenance of normal skin and in the growth and development of the central nervous system. *Pyridoxine,* (Vitamin B_6), is another of the group of the vitamin B complex. Not much is known as to just how it functions, but it is known to be essential to good health and growth. *Folicin* is of value in preventing and curing pernicious anemia. *Inositol* also belongs to the vitamin B complex and is known to be essential to proper nutrition and growth. *Choline* is important to the proper functioning of the liver

TABLE 36. ADDITIONAL NUTRIENT MATERIALS IN DAIRY PRODUCTS

(A compilation of information on members of the vitamin B complex not listed in the foregoing table)

Dairy Product	Average Content—Milligrams Per 100 Grams						
	Biotin	Pantothenic Acid	Pyridoxine	Folacin	Inositol	Choline	Vitamin B_{12}
Whole Milk	0.004	0.350	0.048	0.00023	13	13	0.00056
Evaporated milk	0.009	0.62	0.062	0.0007		26	
Dried skimmed milk	0.029	3.7	0.49	0.0044	60	190	0.0032
Dried whole milk	0.036	2.5	0.38	0.0023		107	0.0038
Cheddar cheese	0.0017	0.18	0.098	0.024		48	0.0015
Dried whey	0.023	4.2	0.44	0.008	24	70	0.0038

and kidneys. The discovery of *vitamin B_{12}* ended a long search for the nutritional factor in liver effective in the treatment of pernicious anemia. This vitamin is believed also to play an essential role in growth and development and appears particularly important in the utilization of protein. Milk and milk products appear to possess vitamin B_{12} activity beyond what might be expected from the amount found in these products.

Miscellaneous Attributes of Milk. Although milk is commonly thought of as a beverage, it is nature's most nearly perfect food and contains more actual solids than many so-called solid foods, especially vegetables. Milk is the only food which is designed by nature solely as a food. It serves as the foundation of an adequate diet. There are several reasons why milk is an important food:

1. It is palatable. Milk, without doubt, is relished by more people than most other foods.

2. It is digestible. The solids in milk are nearly all digestible, and this is something that cannot be said of many other foods. The digestibility of milk is increased somewhat when it is consumed with other foods.

3. It is a food for all ages. This statement is brought out in Fig. 132, which has been prepared by the National Dairy Council. The U.S. Department of Agriculture reports that in recent years consumers spend a little over 15 per cent of their food dollars for dairy products.

4. It is a well-balanced food for growing children. Milk is well adapted to the digestive system of the child. Homogenized vitamin D milk is especially adapted for infant feeding. Homogenization makes the butterfat globules smaller and the curd softer, improving its digestibility. The vitamin D aids formation of bones and teeth. When it is necessary to put the child on cow's milk from the very start, milk may have to be modified by boiling, dilution, acidification, or addition of carbohydrate. The doctor prescribes for this. Cow's milk contains about three times as much protein, two-thirds as much sugar, twice as much mineral matter and slightly more butterfat than human milk.

The practice of using plenty of milk in infancy should be continued by the teenager, when growth and activity make heavy demands. This fact has been recognized in a very practical way with the establishment of the school lunch program. A measure enacted by Congress in 1946 provides that Type A school lunches must contain milk. Millions of children in the United States participate in the school lunch program.

5. Milk is an excellent food for adults. The diet of every adult should include milk, combined with other foods. It is an excellent source of protein; it supplies liberal amounts of the much needed minerals, and it furnishes an easily digestible sugar and fat for energy.

6. Milk and its products are especially good for the elderly, as a source of protein and minerals—especially calcium which is important in helping maintain bone strength. Milk has long been the food given people with various functional disorders and those convalescing from illness.

For weight loss, moderate low calorie diets have been found more satisfying and effective if they contain liberal quantities of protein foods, as milk, cheese, meat, poultry, fish, and eggs. For further in-

Fig. 132. A guide to good eating. (Courtesy National Dairy Council.)

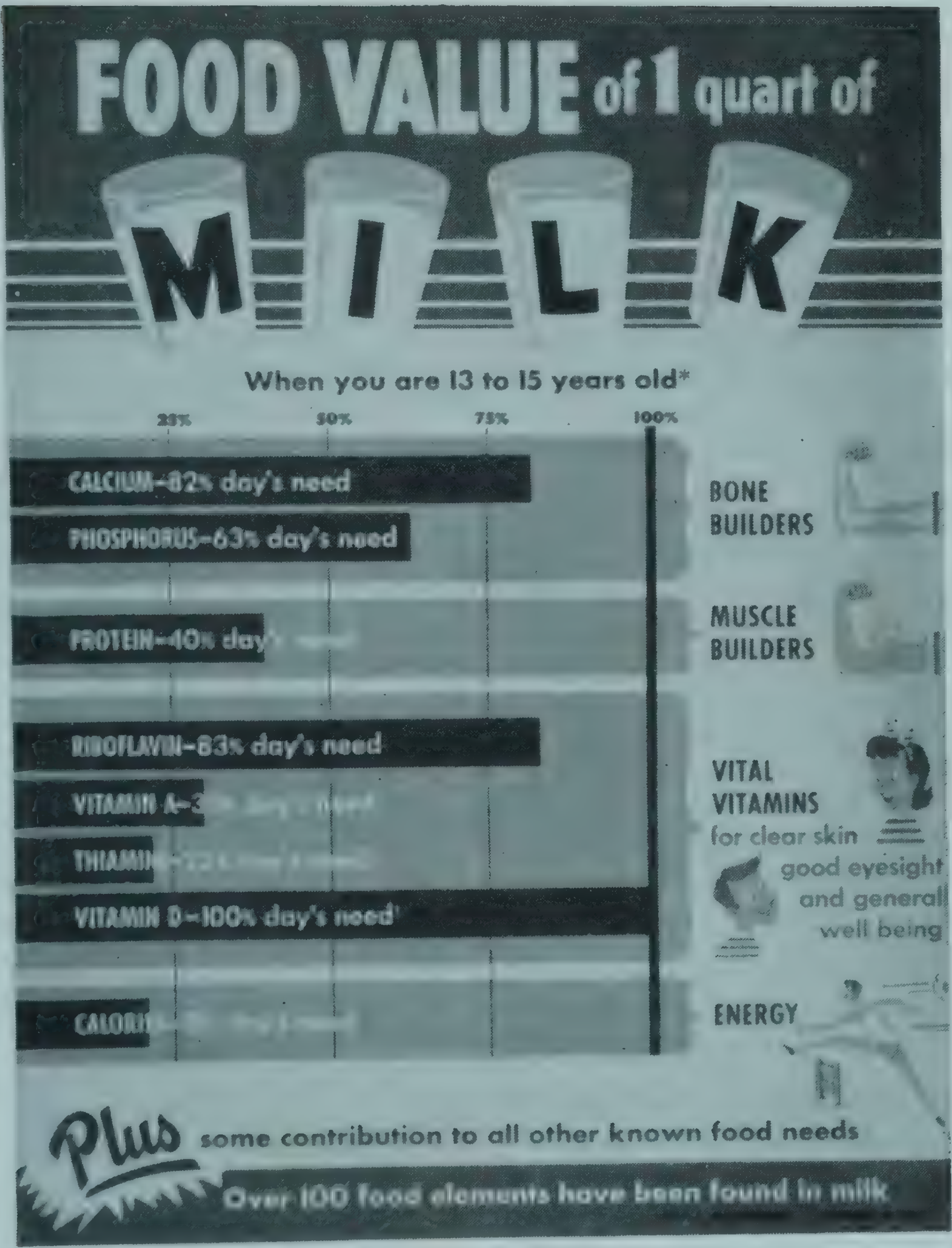

Fig. 133. Food value of milk. (Courtesy National Dairy Council.)

formation, write National Dairy Council, 111 N. Canal Street, Chicago 6, Illinois, for a catalogue of its health education materials.

Pregnant and nursing mothers require extra amounts of milk to provide the extra nutrients and energy needed for the unborn child and for synthesis of milk. Dairy foods also appear to aid dental health, as has been demonstrated in experiments with animals.

7. Milk is inexpensive. Compared with other foods, milk always will be sold on a small margin of profit and always will be relatively inexpensive. Milk is a relatively high protein food and can be compared best with meat. With meat selling at 50 to 80 cents per pound, milk is worth about 50 cents per quart, on the basis of food-value comparison.

8. It requires no preparation for use in the home.

9. It contains no waste. Most foods contain some waste, such as bone, shell or skin, but the bottle of milk may be used to the last drop.

10. It is rich in mineral matter. The minerals in milk are in a very available form. It is especially rich in calcium, which is so necessary for the development of bones and the teeth. A quart of milk furnishes the same amount of calcium as 39 eggs, 28 oranges, 27 lb of potatoes, 7¼ lb carrots, or 6¾ lb of cabbage.

11. It is a food of many uses. Milk may be used as a beverage, in soups, scalloped dishes, gravies, sauces, desserts, breakfast cereals, and for general cooking purposes. When cooking with milk, it is well to remember that milk, when heated with foods that contain acids, tannins (commonly found in many vegetables such as asparagus, stringbeans, peas, or carrots), or salt, may curdle under certain conditions. Ways that may help prevent curdling are:

(*a*) Thicken milk first.
(*b*) Add other ingredients to milk gradually.
(*c*) Avoid overheating.

Homogenized milk may give different results than nonhomogenized milk when used in the cookery of certain products. Recent studies indicate that the protein of homogenized milk is more readily coagulated by heat and acid than the protein of nonhomogenized milk. This coagulation may cause differences in the firmness and stability of milk desserts made with homogenized milk.

Food Value of Other Dairy Products. CREAM. Cream is used primarily because it adds to the tastiness of various beverages, notably coffee, and for various foods, particularly in the dessert group.

Since the butterfat content varies from 10 to 12 per cent for half-and-half and up to 40 per cent for cream, depending upon the type of cream used, the higher the percentage of butterfat in cream, the greater its vitamin A content.

SKIM MILK. Skim milk is high in food value since it contains the non-fat solids of milk, protein, lactose, minerals, and water-soluble vitamins. As people have become more weight conscious during recent years, skim milk has come to be used extensively as a beverage. It also continues to be used extensively in cooking. One cup of skim milk contains more protein than one ounce of round steak.

BUTTER. Butter is used to enhance the taste of various foods, either in cooking or by using as a spread on the finished food. Since butter contains about 80 per cent butterfat, it is an important source of vitamin A in the diet.

CHEESE. Many varieties of cheese are made in this country and abroad. For the purpose of brief discussion, they may be divided into the hard and soft varieties. The hard, or Cheddar, cheese is the type most commonly consumed in this country. The food value of cheese is widely recognized. It is listed with "the meat group" as a source of high-quality protein and can be used in place of meat as a main dish, as such, or combined with other foods. The average person in this country uses about 8 lb of cheese (of the hard types) a year. This is nearly double the 1925–1929 average. European countries are much heavier consumers of cheese; Great Britain uses 10.0 lb per capita annually, France 10.5 lb and Switzerland 24.0 lb. These figures clearly show the possibilities for further development of the cheese industry in America. Cheese is essentially a high-protein food. One pound of Cheddar cheese contains as much protein as

1.57 lb of sirloin steak
1.35 lb of round steak
1.89 lb of fowl
1.75 lb of smoked ham
1.81 lb of fresh ham

Cheddar cheese is one of the best foods available as a source of calcium. As a source of heat and energy, it stands at the top of the list of common articles of food.

Cottage cheese also ranks high in food value; 1 lb of cottage cheese supplies nearly as much protein as 1½ lb of the common cuts of meat. As a source of energy, it is about half as valuable, pound for pound, as meat.

Cheese is easily and thoroughly digested. Experiments show that 90 per cent of the casein of cheese is retained in the body. Cheese can be combined with starchy foods, such as bread and potatoes.

There are many varieties of cheese other than the ones mentioned above. Some of the more common are Camembert, Limburger, and Roquefort. The numerous varieties of cheese present all degrees of flavor, from the milk flavor of cream cheese to the strong flavor of Limburger. These differences are recognized in preparing various foods with cheese. Space will not permit the presentation of recipes for the use of cheese, but a few of the general uses are cheese sauces, cheese fondu, Welsh rabbit, macaroni and cheese, baked rice and cheese, cheese sandwiches, and cheese salads. These cheese dishes not only add variety in the problem of feeding the family but also decrease the size of the food bill.

CONDENSED AND EVAPORATED MILK. Condensed and evaporated milk is milk with approximately 50 per cent of the water evaporated. Condensed milk is preserved by the addition of 40 to 42 per cent cane sugar, whereas evaporated milk has no sugar added to it, but is sterilized in the cans to insure its keeping qualities. Because they can be shipped easily and stored indefinitely, condensed and evaporated milk are used in almost all parts of the world. Tremendous quantities have been used by soldiers in time of war. These products are used extensively for cooking and in the manufacture of ice cream.

ICE CREAM. One-sixth quart of an average commercial vanilla ice cream can supply an individual with significant amounts of his daily need for riboflavin, vitamin A, fat, calcium, phosphorus, and important amounts of energy, protein, and thiamine.

Ice cream is highly digestible, which makes the nutrients it contains readily available to the body. Ice cream contains a variety of nutrients which tend to favor their efficient utilization within the body. The actual food value of ice cream is enhanced by its appetite appeal to individuals of all ages under varying conditions of health.

FERMENTED MILK. Fermented milks are due to bacterial growth, primarily to the formation of lactic acid from lactose. Buttermilk is the most commonly available fermented milk in the United States. Other forms of fermented milk are Acidophilus milk, Kefir, and Yogurt. Fermented milks are made from skim, partially skim, whole, or concentrated whole milk. The starting milk may be fresh, reconstituted spray dried, evaporated, or a combination of these. All fermented milks are pasteurized or sterilized before being cultured

with the desired organisms. The nutritive value of any dairy food, including fermented milks, depends chiefly upon its concentration of milk fat and nonfat milk solids. No difference has been demonstrated between the nutritional value of fresh and fermented milks which contain equal concentrations of milk fat and non-fat milk solids.

There is some clinical evidence that fermented milks have therapeutic value in special diets which may be attributable to their soft curd properties, presence of lactic acid producing organisms, or presence of lactic acid itself.

Care of Milk in the Home. It is important that milk be protected from strong light and particularly so when it is handled in glass bottles. Considerable riboflavin and vitamin C in milk are lost when milk is allowed to stand in sunlight, a sunny window, or unprotected on the doorstep. Sunlight also affects the flavor of milk. Milk standing in sunlight on the doorstep will rapidly develop an off-flavor. If the milk is delivered in clear glass bottles and cannot be refrigerated immediately, provide an insulated receiving box with a cover for it. Milk in cardboard containers will retain more riboflavin when exposed to bright sunlight than will milk in glass bottles.

Keep milk cool. To retain the food value, sanitary quality, and flavor of milk, store it in covered containers in the refrigerator as soon as possible. Remove milk from the refrigerator only as needed, because it is perishable and may spoil rapidly. When stored in the coldest part of the refrigerator, milk may keep its good quality for a week or more. When milk is kept at room temperature for 4 to 5 hours, it may develop off-flavors and odors.

Keep milk clean. Do not mix fresh milk with old unless you plan to use it immediately. The more you handle milk in transferring it from one container to another, the more opportunity there is to introduce contamination.

QUESTIONS

1. What are the essential food requirements necessary to sustain the human body?
2. Is milk peculiar in its high percentage of water?
3. What is the nutritional significance of milk protein?
4. What body functions are served by the butterfat and carbohydrate of milk?

5. How does the calorie value of butterfat compare with that of carbohydrate?
6. What is the importance of minerals in the diet?
7. What are the vitamins found in milk and which is found in the largest quantity?
8. Why are dairy products such an important part of the diet?
9. List the special attributes of milk as a food.
10. What particular function does cream serve in the diet?
11. How does skim milk and whole milk differ in food value?
12. What makes butter such an important food?
13. Why is cheese such a versatile food?
14. What properties do condensed and evaporated milk possess that are not possessed by other dairy products?
15. Does ice cream have value other than its pleasing taste?
16. What are some of the common forms of fermented milk?
17. Do fermented milks have any special value in the diet?
18. List the important directions for the care of milk in the home.

PROBLEMS

1. If milk testing 11.95 per cent total solids (T.S.) sells for 22 cents per qt, what is 13 per cent T.S. milk worth? *Ans.* 23.94 cents

2. A quart of skim milk (2.15 lb) furnishes the same number of food units as 13.33 cents worth of milk at 25 cents per qt; 27.27 cents worth of lamb chops at $1.05 per lb; 58.17 cents worth of round steak at $1.05 per lb; $1.60 worth of oysters at $2.00 per qt; 86.66 cents worth of chicken at 60 cents per lb. Find the amount of these various foodstuffs that is equivalent in food value to one quart of skim milk?
   Ans. 1.15 lb milk, 4.15 oz lamb chops, 8.86 oz round steak, 1.6 pt oysters, 23.10 oz chicken

3. There is as much nourishment in a quart of milk at 24 cents as there is in 45 cents worth of beef at 66 cents per lb or 87 cents worth of eggs at $1.05 per dozen. How much milk would you have to use for breakfast to obtain the equivalent in food value of ½ lb of beefsteak and 3 eggs? *Ans.* 1.03 qt of milk

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APPENDIX A

DAIRY COW UNIFIED SCORE CARD

Breed characteristics should be considered in the application of this score card		Perfect Score
Order of Observation		
1. GENERAL APPEARANCE		30
(*Attractive individuality with femininity, stretch, scale, harmonious blending of all parts, and impressive style and carriage. All parts of a cow should be considered in evaluating a cow's general appearance*)	10	
Breed Characteristics—(see page 395)		
Head—clean-cut, proportionate to body; broad muzzle with large, open nostrils; strong jaws; large, bright eyes; forehead, broad and moderately dished; bridge of nose straight; ears medium size and alertly carried		
Shoulder Blades—set smoothly and tightly against the body	10	
Back—straight and strong; loin, broad and nearly level		
Rump—long, wide, and nearly level from *hock bones* to *pin bones;* clean-cut and free from patchiness; *thurls*, high and wide apart; *tail head*, set level with backline and free from coarseness; *tail*, slender		
Legs and *Feet*—bone flat and strong, pasterns short and strong, hocks cleanly molded. *Feet*, short, compact, and well rounded with deep heel and level sole. *Fore legs*, medium in length, straight, wide apart, and squarely placed. *Hind legs*, nearly perpendicular from hock to pastern, from the side view, and straight from the rear view	10	
2. DAIRY CHARACTER		20
(*Evidence of milking ability, angularity, and general openness, without weakness; freedom from coarseness, giving due regard to period of lactation*)		
Neck—long, lean, and blending smoothly into shoulders; clean-cut throat, dewlap, and brisket. *Withers*, sharp. *Ribs*, wide apart rib bones, wide, flat, and long. *Flanks*, deep and refined. *Thighs*, incurving to flat and wide apart from the rear view, providing ample room for the udder and its rear attachment. *Skin*, loose, and pliable	20	

DAIRY COW UNIFIED SCORE CARD (Continued)

3. BODY CAPACITY *(Relatively large in proportion to size of animal, providing ample capacity, strength, and vigor)*		20
Barrel—strongly supported, long and deep; ribs highly and widely sprung; depth and width of barrel tending to increase toward rear	10	
Heart Girth—large and deep, with well-sprung fore ribs blending into the shoulders; full crops; full at elbows; wide chest floor	10	
4. MAMMARY SYSTEM *(A strongly attached, well-balanced, capacious udder of fine texture indicating heavy production and a long period of usefulness)*		30
Udder—symmetrical, moderately long, wide and deep, strongly attached, showing moderate cleavage between halves, no quartering on sides; soft, pliable, and well collapsed after milking; quarters evenly balanced	10	
Fore Udder—moderate length, uniform width from front to rear, and strongly attached	6	
Rear Udder—high, wide, slightly rounded, fairly uniform width from top to floor, and strongly attached	7	
Teats—uniform size, of medium length and diameter, cylindrical, squarely placed under each quarter, plumb, and well spaced from side and rear views	5	
Mammary Veins—large, long, tortuous, branching "Because of the natural undeveloped mammary system in heifer calves and yearlings, less emphasis is placed on mammary system and more on general appearance, dairy character, and body capacity. A slight to serious discrimination applies to overdeveloped, fatty udders in heifer calves and yearlings."	2	
TOTAL		100

Courtesy The Purebred Dairy Cattle Association, 1957 Revision.

BREED CHARACTERISTICS FOR COWS

AYRSHIRE

Strong and robust, showing constitution and vigor, symmetry, style, and balance throughout, and characterized by strongly attached, evenly balanced, well-shaped udder.

Color—Light to deep cherry red, mahogany brown, or a combination of any of these colors with white, or white alone, distinctive red and white markings preferred, black or brindle objectionable.

Size—A mature cow in milk should weigh at least 1200 lb.

Horns—Inclining upward, refined, medium length, and tapered toward tips. No discrimination for absence of horns.

GUERNSEY

Size and strength, with quality and character desired.

Color—A shade of fawn with white markings clearly defined. Skin should show golden yellow pigmentation. When other points are equal, a clear (buff) muzzle will be favored over a smoky or black muzzle.

Size—A mature cow in milk should weigh at least 1100 lb. "In milk" means normal condition after having been in milk 3 to 6 months.

Horns—No discrimination for absence of horns.

JERSEY

Sharpness with strength indicating productive efficiency.

Color—A shade of fawn, with or without white markings.

Size—A mature cow in milk should weigh about 1000 lb.

Horns—Incurving, refined, medium length, and tapering toward tips. No discrimination for absence of horns.

BROWN SWISS

Strong and vigorous, but not coarse. Size and ruggedness with quality desired. Extreme refinement undesirable.

Color—Solid brown varying from very light to dark. White or off-color spots objectionable. Females with any white or off-color markings above the underside of the belly, or with white core in switch, do not meet color standards of the Brown Swiss breed, and shall be so designated when registered. Pink noses and light streaks up the side of the face objectionable.

Size—The minimum weight for mature cows should be about 1400 lb.

Horns—Incurving and inclining slightly up. Of medium length, lacking coarseness, tapering toward tips. Polled animals not barred from registry. No discrimination for absence of horns.

HOLSTEIN

Rugged, femine qualities in an alert cow possessing Holstein size and vigor.

Color—Black and white markings clearly defined. Color markings that bar registry are solid black, solid white, black in switch, black belly, black encircling leg touching hoof head, black from hoof to knee or hock, black and white intermixed to give color other than distinct black and white.

Size—A mature cow in milk should weigh at least 1500 lb.

Horns—No discrimination for absence of horns.

Courtesy The Purebred Dairy Cattle Association, 1957 Revision.

EVALUATION OF DEFECTS IN COWS

In a show ring, disqualification means that the animal is not eligible to win a prize. Any disqualified animal is not eligible to be shown in the group classes. In slight to serious discrimination, the degree of seriousness shall be determined by the judge.

EYES

1. Total blindness: Disqualification.
2. Blindness in one eye: Slight discrimination.
3. Cross-eyes: Slight discrimination.

WRY FACE

Slight to serious discrimination.

CROPPED EARS

Slight discrimination.

PARROT JAW

Slight to serious discrimination.

SHOULDERS

Winged: Slight to serious discrimination.

TAIL SETTING

Wry tail or other abnormal tail settings: Slight to serious discrimination.

LEGS AND FEET

1. Lameness—apparently permanent and interfering with normal function: Disqualification.
   —apparently temporary and not affecting normal function: Slight discrimination.
2. Bucked knees: Slight to serious discrimination.
3. Evidence of arthritis, crampy hind leg: Serious discrimination.
4. Boggy hocks: Slight to serious discrimination.

ABSENCE OF HORNS

No discrimination.

LACK OF SIZE

Slight to serious discrimination.

UDDER

1. Blind quarter: Disqualification.
2. Abnormal milk (bloody, clotted, watery): Possible disqualification.
3. Udder definitely broken away in attachment: Serious discrimination.
4. A weak udder attachment: Slight to serious discrimination.
5. One or more light quarters, hard spots in udder, obstruction in teat (spider): Slight to serious discrimination.
6. Side leak: Slight discrimination.

DRY COWS

Among cows of apparently equal merit: Give strong preference to cows in milk.

FREEMARTIN HEIFERS

Disqualification unless proved pregnant.

OVERCONDITIONED

Slight to serious discrimination.

TEMPORARY OR MINOR INJURIES

Blemishes or injuries of a temporary character not affecting animal's usefulness: Slight discrimination.

EVIDENCE OF SHARP PRACTICE

1. Animals showing signs of having been operated upon or tampered with for the purpose of concealing faults in conformation, or with intent to deceive relative to the animal's soundness: Disqualification.
2. Uncalved heifers showing evidence of having been milked: Serious discrimination.

Courtesy The Purebred Dairy Cattle Association, 1957 Revision.

APPENDIX B

DAIRY BULL UNIFIED SCORE CARD

Breed characteristics should be considered in the application of this score card		Perfect Score
Order of observation		
1. GENERAL APPEARANCE		45
(*Attractive individuality, with masculinity, vigor, stretch, and scale. Harmonious blending of all parts, and impressive style and carriage. All parts of a bull should be considered in evaluating a bull's general appearance*)		
Breed Characteristics—(see page 398)	15	
Head—clean cut, proportionate to body; broad muzzle with large, open nostrils; strong jaws; large, bright eyes; forehead, broad and moderately dished; bridge of nose straight; ears medium size and alertly carried		
Shoulder Blades—set smoothly, tightly against body	15	
Back—straight and strong; loin, broad and nearly level		
Rump—long, wide, and nearly level from *hock bones* to *pin bones;* clean cut and free from patchiness; *thurls*, high and wide apart; *tail head*, set level with backline and free from coarseness; *tail*, slender		
Legs and Feet—bone flat and strong, pasterns short and strong, hocks cleanly molded. *Feet*, short, compact, and well rounded with deep heel and level sole. *Fore legs*, medium in length, straight and wide apart, squarely placed. *Hind legs*, nearly perpendicular from hock to pastern from the side view, and straight from the rear view	15	
2. DAIRY CHARACTER		30
(*Angularity and general openness, without weakness; freedom from coarseness*)		
Neck—long, with medium crest and blending smoothly into shoulders; clean-cut throat, dewlap, and brisket. *Withers*, sharp. *Ribs*, wide apart, rib bones wide, flat, and long. *Flanks*, deep and refined. *Thighs*, incurving to flat, and wide apart from the rear view. *Skin*, loose and pliable	30	
3. BODY CAPACITY		25
(*Relatively large in proportion to size of animal, providing ample capacity, strength, and vigor*)		
Barrel—strongly supported, long, and deep; ribs highly and widely sprung; depth and width of barrel tending to increase toward rear	12	
Heart Girth—large and deep, with well sprung fore ribs blending into the shoulders; full crops; full at elbows; wide chest floor	13	
TOTAL		100

BREED CHARACTERISTICS FOR BULLS

AYRSHIRE

Strong and robust, showing constitution and vigor, symmetry, style and balance throughout.

Color—Light to deep cherry red, mahogany brown, or a combination of any of these colors with white, or white alone, distinctive red and white markings preferred, black or brindle objectionable. Red markings usually a deeper shade on the bull than on the cow.

Size—A mature bull in breeding condition should weigh at least 1850 lb.

Horns—Inclining upward, medium size, medium length, and tapered toward tips. No discrimination for absence of horns.

GUERNSEY

Size, strength, and vigor, with quality and character desired.

Color—A shade of fawn with white markings clearly defined. Skin should show golden yellow pigmentation. When other points are equal, a clear (buff) muzzle will be favored over a smoky or black muzzle.

Size—A mature bull in breeding condition should weigh about 1700 lb.

Horns—No discrimination for absence of horns.

JERSEY

Strong and vigorous, size and ruggedness with quality desired.

Color—A shade of fawn, with or without white markings.

Size—A mature bull in breeding condition should weigh about 1500 lb.

Horns—Incurving, refined, medium length, and tapering toward tips. No discrimination for absence of horns.

BROWN SWISS

Strong and vigorous, but not coarse. Size and ruggedness with quality desired. Extreme refinement undesirable.

Color—Solid brown preferred, varying from light to very dark. White or off-color spots are objectionable. Males with any white or off-color markings, or with white core in switch, do not meet color standards of the Brown Swiss breed, and shall be so designated when registered. Pink noses and light streaks up the side of the face objectionable.

Size—The minimum weight for mature bulls should be about 2000 lb.

Horns—Tending to incline slightly forward, of medium length, not coarse, tapering toward tips. Polled animals not barred from registry. No discrimination for absence of horns.

HOLSTEIN

Strong masculine qualities in an alert bull possessing Holstein size and vigor.

Color—Black and white markings clearly defined. Color markings that bar registry are solid black, solid white, black in switch, black belly, black encircling leg touching hoof head, black from hoof to knee or hock, black and white intermixed to give color other than distinct black and white.

Size—A mature bull in breeding condition should weigh at least 2200 lb.

Horns—No discrimination for absence of horns.

Courtesy The Purebred Dairy Cattle Association, 1957 Revision.

EVALUATION OF DEFECTS IN BULLS

In a show ring, disqualification means that the animal is not eligible to win a prize. Any disqualified animal is not eligible to be shown in the group classes. In slight to serious discrimination, the degree of seriousness shall be determined by the judge.

EYES

1. Total blindness: Disqualification.
2. Blindness in one eye: Slight discrimination.
3. Cross-eyes: Slight discrimination.

WRY FACE

Slight to serious discrimination.

CROPPED EARS

Slight discrimination.

PARROT JAW

Slight to serious discrimination.

SHOULDERS

Winged: Slight to serious discrimination.

TAIL SETTING

Wry tail or other abnormal tail settings: Slight to serious discrimination.

LEGS AND FEET

1. Lameness—apparently permanent and interfering with normal function: Disqualification.
   —apparently temporary and not affecting normal function: Slight discrimination.
2. Bucked knees: Slight to serious discrimination.
3. Evidence of arthritis, crampy hind leg: Serious discrimination.
4. Boggy hocks: Slight to serious discrimination.

ABSENCE OF HORNS

No discrimination.

LACK OF SIZE

Slight to serious discrimination.

TESTICLES

Bull with one testicle or with abnormal testicles: Disqualification.

OVERCONDITIONED

Slight to serious discrimination.

TEMPORARY OR MINOR INJURIES

Blemishes or injuries of a temporary character not affecting animal's usefulness: Slight discrimination.

EVIDENCE OF SHARP PRACTICE

Animals showing signs of having been operated upon or tampered with for the purpose of concealing faults in conformation, or with intent to deceive relative to the soundness: Disqualification.

Courtesy The Purebred Dairy Cattle Association, 1957 Revision.

DAILY NUTRIENT REQUIREMENTS OF DAIRY CATTLE

(Based on air-dry feed containing 90 per cent dry matter)

	Daily Gain		Daily Nutrients per Animal[1]								
Body Wgt., lb	Small Breeds, lb	Large Breeds, lb	Feed, lb	Protein, lb	Digestible Protein, lb	TDN, lb	DE,[2] therm	Ca, gm	P, gm	Carotene, mg	Vitamin D, I.U.
			Normal Growth of Dairy Heifers								
50	0.5	—	0.9	0.31	0.20	1.0	2.0	4	3	2[3]	150
100	1.0	0.8	2.0	0.62	0.40	2.0	4.0	7	6	4	300
150	1.3	1.4	4.0	0.78	0.50	3.0	6.1	12	10	6	450
200	1.4	1.6	6.0	0.94	0.60	4.0	8.1	13	10	8	600
400	1.2	1.8	11.0	1.25	0.80	6.5	13.1	13	12	16	[4]
600	0.8	1.4	15.0	1.33	0.85	8.5	17.1	13	12	24	—
800	1.1	1.2	19.0	1.40	0.90	10.0	20.2	13	12	32	—
1000	—	1.3	22.0	1.48	0.95	11.0	22.2	12	12	40	—
1200	—	1.2	24.0	1.56	1.00	12.0	24.2	12	12	48	—
			Maintenance of Mature Cows[5]								
800	—	—	12	0.95	0.50	5.8	11.7	6	6	32	[4]
1000	—	—	14	1.13	0.60	7.0	14.1	8	8	40	—
1200	—	—	16	1.32	0.70	8.2	16.6	10	10	48	—
1400	—	—	19	1.51	0.80	9.4	19.0	11	11	56	—
1600	—	—	21	1.64	0.87	10.5	21.2	12	12	64	—
			Reproduction (Add to Maintenance during last 2 to 3 Months)								
—	2.0	2.0	8.0	1.13	0.60	6.0	12.1	8	7	30	[4]
			Lactation (Add to Maintenance for Each Pound of Milk)								
—	—	3.0% fat	—	0.062	0.040	0.28	0.57	1	0.7	[6]	[6]
—	—	4.0% fat	—	0.070	0.045	0.32	0.65	1	0.7	—	—
—	—	5.0% fat	—	0.078	0.050	0.37	0.75	1	0.7	—	—
—	—	6.0% fat	—	0.086	0.055	0.42	0.85	1	0.7	—	—
			Maintenance of Breeding Bulls								
1200	—	—	18	1.56	1.00	10.3	20.8	10	10	48	—
1600	—	—	22	1.87	1.20	12.9	26.1	12	12	64	—
2000	—	—	27	2.20	1.45	15.6	31.5	16	16	80	—
2400	—	—	31	2.50	1.60	18.2	36.8	19	19	96	—

NOTES FOR DAILY NUTRIENT REQUIREMENTS OF DAIRY CATTLE

[1] Thiamine, riboflavin, niacin, pyridoxine, pantothenic acid, folic acid, vitamin B_{12}, and vitamin K are synthesized by bacteria in the rumen, and it appears that adequate amounts of these vitamins are furnished by a combination of rumen synthesis and natural feedstuffs. Manganese, magnesium, iron, copper, and cobalt are essential, and the amounts needed are discussed in the text.

[2] DE (digestible energy) was calculated on the assumption that one gram of TDN has 4.45 kcal. of digestible energy, a value based largely on the extensive summary of published data made by B. H. Schneider. DE may be converted to metabolizable energy by multiplying by 82%.

[3] Calves should receive colostrum the first few days after birth, as a source of vitamin A and other essential factors.

[4] While vitamin D is known to be required, the data are inadequate to warrant specific figures for older growing animals and for maintenance, reproduction, and lactation.

[5] When calculating the intakes for lactating heifers that are still growing, it is recommended that the figure for growth rather than maintenance be used.

[6] When adequate amounts of vitamins A and D are fed for normal reproduction, extra amounts will not stimulate milk production but will increase the vitamin content of the milk.

Courtesy National Academy of Sciences—National Research Council.

NUTRIENT CONTENT OF RATIONS FOR DAIRY CATTLE
(Based on air-dry feed containing 90 per cent dry matter)

	Average Age		Per Cent of Ration or Amount per Pound of Feed								
Body Wgt., lb	Small Breeds, mo.	Large Breeds, mo.	Total Daily, lb	Feed % of Wgt., %	Digestible Protein, %	TDN, %	DE,[1] therms /lb	Ca, %	P, %	Carotene, mg/lb	Vitamin D, I.U./lb
					Normal Growth of Dairy Heifers						
50	Birth	—	0.9	1.6	22.0	110	2.22	0.98	0.73	—	170
100	2.3	0.6	2.0	2.0	20.0	100	2.02	0.77	0.66	2.0	150
150	3.7	2.0	4.0	2.7	12.5	75	1.52	0.66	0.44	1.5	110
200	4.8	3.1	6.0	3.0	10.0	67	1.35	0.48	0.40	1.3	100
400	10.0	6.7	11.0	2.8	7.3	59	1.19	0.26	0.30	1.5	—
600	17.2	10.8	15.0	2.7	5.7	57	1.15	0.19	0.22	1.6	—
800	28.0	16.0	19.0	2.5	4.7	53	1.07	0.15	0.15	1.7	—
1000	—	22.0	22.0	2.2	4.3	50	1.01	0.13	0.13	1.8	—
1200	—	36.0	24.0	2.0	4.2	50	1.01	0.12	0.12	2.0	—
					Maintenance of Mature Cows						
800	—	—	12	1.8	3.6	50	1.01	0.12	0.12	2.3	—
1000	—	—	14	1.6	3.7	50	1.01	0.12	0.12	2.5	—
1200	—	—	16	1.5	3.9	50	1.01	0.12	0.12	2.7	—
1400	—	—	19	1.4	3.8	50	1.01	0.12	0.12	2.7	—
1600	—	—	21	1.3	3.8	50	1.01	0.12	0.12	2.8	—
					Lactating Cows						
—	—	—	—	—	6.5	60	1.21	0.30	0.25	1.2	—
					Maintenance of Breeding Bulls						
1200	—	—	18	1.5	5.6	58	1.17	0.12	0.12	2.7	—
1600	—	—	22	1.4	5.5	58	1.17	0.13	0.13	2.9	—
2000	—	—	27	1.3	5.4	58	1.17	0.13	0.13	3.0	—
2400	—	—	31	1.3	5.2	58	1.17	0.14	0.14	3.1	—

[1] DE (digestible energy) may be converted to metabolizable energy by multiplying by 82 per cent.

Courtesy National Academy of Sciences—National Research Council.

AVERAGE COMPOSITION AND DIGESTIBLE NUTRIENTS

Feedstuff	Total Dry Matter, %	Protein, %	Dig. Protein, %	TDN,[1] %	DE,[2] therms /lb	Calcium, %	Phosphorus, %	Carotene, mg/lb
				Dry Roughages				
Alfalfa hay, all analyses	90.5	15.3	10.9	50.7	1.02	1.47	0.24	8.2
Alfalfa hay, 1/10 to 1/2 bloom	90.5	15.4	11.2	51.4	1.04	1.47	0.24	20.3
Alfalfa hay, 3/4 to full bloom	90.5	14.1	10.2	50.3	1.02	1.22	0.22	8.5
Alfalfa hay, past bloom	90.5	12.9	9.3	47.7	0.96	1.10	0.20	3.3
Alfalfa meal, dehydrated	92.7	17.7	12.4	54.4	1.10	1.60	0.26	42.4
Alfalfa leaf meal, dehydrated	92.7	21.1	16.0	57.2	1.16	1.69	0.25	62.9
Barley hay	90.8	7.3	4.0	51.9	1.05	0.26	0.23	—
Barley straw	90.0	3.7	0.7	42.2	0.85	0.33	0.10	—
Birdsfoot trefoil hay	91.2	14.2	9.8	55.0	1.11	1.60	0.20	19.7
Bromegrass hay, all analyses	88.8	10.4	5.3	49.3	1.00	0.42	0.19	—
Clover hay, alsike, all analyses	88.9	12.1	8.1	53.2	1.07	1.15	0.23	—
Clover hay, crimson	89.5	14.2	9.8	48.9	0.99	1.23	0.24	—
Clover hay, Ladino	89.5	18.5	14.2	59.5	1.20	1.53	0.29	—
Clover hay, red, all analyses	88.3	12.0	7.2	51.8	1.05	1.28	0.20	7.3
Clover and mixed grass hay, high in clover	89.6	9.6	5.5	51.8	1.05	0.88	0.21	6.1
Clover and timothy hay, 30 to 50% clover	88.1	8.6	4.7	51.0	1.03	0.69	0.16	—
Corn cobs, ground	90.4	2.3	0.0	45.7	0.92	0.11	0.04	—
Corn fodder, medium, in water	82.6	6.8	3.3	53.9	1.09	0.25	0.14	1.8
Corn stover, medium, in water	80.3	5.8	2.0	45.5	0.92	0.48	0.08	—
Cowpea hay, all analyses	90.4	18.6	12.3	51.4	1.04	1.37	0.30	—
Kafir fodder, very dry	90.0	8.7	4.5	53.6	1.08	0.35	0.18	2.0
Kafir stover, very dry	90.0	5.5	1.9	51.3	1.04	0.54	0.09	1.1
Lespedeza hay, annual, before bloom	89.1	14.3	7.2	49.2	0.99	1.03	0.20	20.4
Lespedeza hay, annual, in bloom	89.1	13.0	6.4	46.4	0.94	1.00	0.19	—
Lespedeza hay, annual, after bloom	89.1	11.5	3.6	39.6	0.80	0.90	0.15	—
Mixed hay, good, less than 30% legumes	89.2	8.8	4.8	48.8	0.99	0.90	0.19	6.4
Oat hay	88.1	8.2	4.9	47.3	0.96	0.21	0.19	—
Oat straw	89.8	4.1	0.7	44.8	0.90	0.24	0.09	—
Orchard grass hay, good	88.7	8.1	4.2	49.7	1.00	0.27	0.18	—
Pea hay, field	89.3	14.9	10.6	55.1	1.11	1.22	0.25	—
Peanut hay, mowed	91.4	10.6	6.9	58.4	1.18	—	—	8.0
Prairie hay, western, cut in midseason	91.3	6.0	2.0	45.1	0.91	0.33	0.12	9.1

Courtesy National Academy of Sciences—National Research Council.

AVERAGE COMPOSITION AND DIGESTIBLE NUTRIENTS
(Continued)

Feedstuff	Total Dry Matter, %	Protein, %	Dig. Protein, %	TDN,[1] %	DE,[2] therms /lb	Calcium, %	Phosphorus, %	Carotene, mg/lb
			Dry Roughages—*Continued*					
Prairie hay, western, mature	91.9	4.4	0.9	43.7	0.88	0.36	0.08	3.6
Quack grass hay	89.0	6.9	2.5	40.3	0.81	—	—	—
Reed canary grass hay	91.1	7.7	4.9	45.1	0.91	0.33	0.16	—
Rye hay	91.3	6.7	2.4	42.5	0.86	—	0.18	—
Rye straw	92.8	3.5	0	42.2	0.85	0.26	0.09	—
Sorghum fodder, sweet, dry	88.9	6.2	3.3	52.4	1.06	0.34	0.14	1.1
Soybean hay, good, all analyses	88.1	14.6	9.8	48.6	0.98	1.10	0.22	13.6
Soybean hay, in bloom or before	88.0	16.7	12.0	52.4	1.06	1.29	0.34	—
Soybean hay, seed developing	88.0	14.6	9.8	48.2	0.97	1.24	0.25	13.6
Soybean hay, seed nearly ripe	88.0	15.2	10.8	54.9	1.11	0.96	0.31	3.0
Soybean straw	88.9	3.9	1.1	38.6	0.78	—	0.05	—
Sudan grass hay, all analyses	89.4	8.8	4.3	48.6	0.98	0.36	0.27	—
Timothy hay, all analyses	89.0	6.6	3.0	49.1	0.99	0.35	0.14	4.4
Timothy hay, before bloom	89.0	9.7	6.1	56.6	1.14	—	—	9.2
Timothy hay, full bloom	89.0	6.4	3.2	51.1	1.03	—	0.20	4.2
Timothy hay, late seed	89.0	5.3	1.9	41.9	0.85	0.14	0.15	2.5
Timothy and clover hay, ¼ clover	88.8	7.9	4.0	49.8	1.01	0.58	0.15	—
Vetch and oat hay, over ½ vetch	87.6	11.9	8.4	50.7	1.02	0.76	0.27	—
Wheat hay	90.4	6.1	3.3	46.7	0.94	0.14	0.18	—
Wheat straw	92.6	3.9	0.3	40.6	0.82	0.15	0.07	—
			Silages, Roots, and Tubers					
Alfalfa, not wilted, no preservative	24.7	4.1	2.6	13.5	0.27	0.35	0.08	15.1
Alfalfa, wilted	36.2	6.3	4.3	21.5	0.43	0.51	0.12	11.4
Alfalfa-molasses, not wilted	26.8	4.1	2.7	15.4	0.31	0.41	0.08	14.5
Beet top, sugar	31.6	3.8	2.5	14.9	0.30	0.31	0.07	5.1
Cabbage, entire	9.4	2.2	1.9	8.1	0.16	0.06	0.03	—
Carrots, roots	11.9	1.2	0.9	10.3	0.21	0.05	0.04	—
Clover, Ladino, and timothy	29.9	5.4	3.9	21.4	0.43	0.31	0.07	15.6
Corn, canning factory waste	22.4	2.0	1.1	16.1	0.33	—	—	—
Corn, dent, well matured, all analyses	27.6	2.3	1.2	18.3	0.37	0.10	0.07	5.8

AVERAGE COMPOSITION AND DIGESTIBLE NUTRIENTS
(Continued)

Feedstuff	Total Dry Matter, %	Protein, %	Dig. Protein, %	TDN,[1] %	DE,[2] therms /lb	Calcium, %	Phosphorus, %	Carotene, mg/lb
			Silages, Roots, and Tubers—*Continued*					
Corn, dent, well matured, well eared	28.5	2.3	1.3	19.8	0.40	0.09	0.07	—
Corn, dent, well matured, fair in ears	26.3	2.1	1.1	17.2	0.35	0.09	0.06	—
Corn, dent, immature, before dough stage	20.3	1.8	0.9	12.9	0.26	0.11	0.07	—
Corn stover, mature ears removed	23.7	1.6	0.6	14.0	0.28	0.08	0.10	—
Corn and soybeans, well matured 30% or more soybeans	28.3	3.2	2.0	19.7	0.40	0.20	0.08	—
Grass silage, considerable legumes	25.6	3.6	2.0	15.5	0.31	—	—	17.1
Grass silage, some legumes	27.6	3.2	1.9	15.6	0.32	—	—	20.7
Grass silage, some legumes, molasses added	25.8	3.2	1.9	15.1	0.31	0.32	0.12	—
Grass silage wilted, molasses added	33.6	4.5	2.6	19.1	0.39	—	—	6.2
Mangels, roots	9.2	1.3	0.9	7.1	0.14	0.02	0.02	—
Oats, molasses added	32.0	2.7	1.4	16.9	0.34	0.10	0.09	17.7
Pea vine	24.5	3.2	1.9	14.0	0.30	0.32	0.06	21.0
Potatoes, tubers	21.2	2.2	1.3	17.4	0.35	0.01	0.05	—
Potato-alfalfa hay	35.9	5.3	3.3	21.1	0.43	—	—	—
Potato-mixed hay	33.7	3.8	2.2	21.6	0.44	—	—	—
Potato-corn meal	31.7	2.0	1.0	27.0	0.55	—	—	—
Rutabagas, roots	11.1	1.3	1.0	9.5	0.19	0.05	0.03	—
Sorghum, sweet	25.4	1.6	0.8	15.2	0.31	0.08	0.05	2.7
Soybean, not wilted	24.8	4.2	2.9	14.6	0.29	0.35	0.09	14.6
Sudan grass	25.7	2.2	1.5	14.4	0.29	0.11	0.04	—
Timothy, not wilted, no preservative	30.9	3.3	1.8	18.4	0.37	0.18	0.09	14.1
Timothy, not wilted, molasses added	30.0	3.1	1.6	17.1	0.35	0.16	0.08	—
Turnips	9.3	1.3	0.9	7.8	0.16	0.06	0.02	—
				Concentrates				
Barley, excluding Pacific Coast	89.4	12.7	10.0	77.7	1.57	0.06	0.40	—
Barley, Pacific Coast	89.9	8.7	6.9	78.8	1.59	0.06	0.33	—

AVERAGE COMPOSITION AND DIGESTIBLE NUTRIENTS
(Continued)

Feedstuff	Total Dry Matter, %	Protein, %	Dig. Protein, %	TDN,[1] %	DE,[2] therms /lb	Calcium, %	Phosphorus, %	Carotene, mg/lb
	Concentrates—*Continued*							
Beans, field or navy	90.0	22.9	20.2	78.7	1.59	0.15	0.57	—
Beet pulp, dried	90.8	9.1	4.3	68.2	1.38	0.68	0.10	—
Beet pulp, molasses, dried	92.0	9.1	6.0	72.3	1.46	0.56	0.08	—
Beet pulp, wet	11.6	1.5	0.8	8.8	0.18	0.09	0.01	—
Blood meal	90.5	79.9	56.7	58.9	1.19	0.28	0.22	—
Blood flour	90.8	82.2	78.9	81.2	1.64	0.45	0.37	—
Bone meal, raw	93.2	26.2	18.1	18.1	0.37	22.14	10.35	—
Bone meal, steamed	95.2	12.1	—	—	—	28.98	13.59	—
Brewers' dried grains	92.4	25.9	20.7	66.0	1.33	0.27	0.50	—
Buttermilk, dried	92.5	32.0	28.8	83.0	1.68	1.34	0.94	—
Citrus pulp, dried	90.1	6.6	5.2	78.2	1.58	1.96	0.12	—
Coconut oil meal, expeller	92.8	20.4	17.3	76.3	1.54	0.21	0.61	—
Coconut oil meal, solvent	91.7	21.3	18.1	68.3	1.38	0.17	0.61	—
Corn and cob meal	86.1	7.4	5.4	73.2	1.48	0.04	0.22	—
Corn, yellow dent, #2	85.0	8.7	6.7	80.1	1.62	0.02	0.27	1.3
Corn, flint	88.5	9.8	7.5	83.4	1.68	—	0.33	—
Corn distillers' dried grains	92.3	27.1	19.8	82.7	1.67	0.09	0.37	1.4
Corn distillers' dried grains, with solubles	91.9	27.2	19.9	81.0	1.64	0.17	0.68	1.7
Corn distillers' dried solubles	93.1	26.9	21.3	80.2	1.62	0.35	1.37	0.3
Corn gluten feed	90.4	25.3	21.8	75.4	1.52	0.46	0.77	3.8
Corn gluten meal	90.7	42.9	36.5	79.9	1.61	0.16	0.40	7.4
Cottonseed, whole, pressed	92.4	28.0	20.2	58.6	1.18	0.17	0.64	—
Cottonseed feed	90.8	39.2	30.6	65.4	1.32	0.15	0.64	—
Cottonseed oil meal, expeller	92.7	41.4	34.4	73.4	1.48	0.18	1.15	—
Cottonseed oil meal, solvent	91.4	41.6	34.5	66.1	1.34	0.15	1.10	—
Fish meal, menhaden	92.2	61.3	49.7	67.0	1.35	5.49	2.81	—
Flaxseed screenings	91.4	15.8	8.8	58.5	1.18	0.37	0.43	—
Flaxseed screenings oil feed	91.3	24.1	13.5	54.6	1.10	0.44	0.63	—
Hominy feed, white	89.8	11.1	7.9	82.9	1.67	0.02	0.58	—
Hominy feed, yellow	90.7	11.1	7.9	83.7	1.69	0.05	0.52	3.1
Linseed feed	90.5	33.8	28.4	74.2	1.50	0.43	0.65	—
Linseed oil meal, expeller	90.9	35.3	30.7	76.3	1.54	0.44	0.89	—
Linseed oil meal, solvent	90.9	35.1	29.5	71.0	1.43	0.40	0.83	—
Meat scrap	93.5	53.4	43.8	65.4	1.32	7.9	4.03	—
Meat scrap, 50% protein	94.0	50.6	41.5	62.2	1.26	10.57	5.07	—
Milk, cow's	12.8	3.5	3.3	16.3	0.33	0.12	0.10	—
Milk, ewe's	19.2	6.5	6.2	26.2	0.53	0.21	0.12	—

AVERAGE COMPOSITION AND DIGESTIBLE NUTRIENTS
(Continued)

Feedstuff	Total Dry Matter, %	Protein, %	Dig. Protein, %	TDN,[1] %	DE,[2] therms /lb	Calcium, %	Phosphorus, %	Carotene, mg/lb
				Concentrates—Continued				
Molasses, beet	76.0	6.7	3.5	59.6	1.20	0.16	0.03	—
Molasses, cane	74.5	3.2	2.0	54.9	1.11	0.89	0.08	—
Molasses, cane, dried	96.1	10.3	—	62.6	1.26	—	—	—
Oats, excluding Pacific Coast	90.2	12.0	9.4	70.1	1.42	0.09	0.33	—
Oats, Pacific Coast	91.2	9.0	7.0	72.2	1.46	—	—	—
Oats, rolled (oatmeal)	90.8	16.1	14.5	91.4	1.85	0.07	0.46	—
Oat groats (hulled)	90.4	16.2	14.6	91.9	1.86	0.08	0.46	—
Orange pulp, dried	89.3	7.0	5.5	78.8	1.59	0.63	0.10	—
Oyster shell, ground	99.6	1.0	—	—	—	38.05	0.07	—
Peanut oil meal, expeller	92.0	45.8	41.7	80.2	1.62	0.17	0.57	—
Peanut oil meal, solvent	91.5	47.4	43.1	74.3	1.50	0.20	0.65	—
Potato meal, dried	90.3	5.9	2.1	65.1	1.32	—	—	—
Rape seed	90.5	20.4	17.3	117.1	2.37	—	—	—
Rice bran	90.6	13.5	9.2	71.0	1.43	0.06	1.82	—
Rice polishings	89.9	11.8	9.0	83.0	1.68	0.04	1.42	—
Rye grain	89.5	12.6	10.0	76.5	1.55	0.10	0.33	—
Rye distillers' dried grains	93.0	22.4	13.4	60.2	1.22	0.13	0.41	—
Rye middlings	89.8	17.1	13.0	71.4	1.44	0.06	0.63	—
Safflower oil meal, expeller	90.6	19.7	15.8	48.4	0.98	0.23	0.71	—
Safflower oil meal, with hulls	93.2	23.7	19.0	51.5	1.04	—	—	—
Safflower oil meal, without hulls	91.1	38.4	33.8	64.4	1.30	0.31	0.58	—
Safflower seed	93.1	16.3	13.0	82.4	1.66	—	—	—
Skim milk, dried	93.9	33.5	30.2	80.3	1.62	1.26	1.03	—
Sorghum, kafir	89.8	11.0	8.9	81.6	1.65	0.03	0.31	—
Sorghum, milo	89.0	10.9	8.5	79.4	1.60	0.03	0.28	—
Sorghum, milo, head chops	89.6	9.2	7.0	74.3	1.50	0.14	0.26	—
Soybeans	90.0	37.9	33.7	87.6	1.77	0.25	0.59	—
Soybean oil meal, expeller	89.7	43.8	36.8	77.0	1.56	0.27	0.63	—
Soybean oil meal, solvent	89.3	45.8	42.1	77.2	1.56	0.32	0.67	—
Sweet potato meal	90.2	4.9	0.7	72.7	1.47	0.15	0.14	32.2
Tankage,-digester	92.1	59.8	50.8	66.1	1.34	5.94	3.17	—
Tankage, digester, with bone	94.1	49.6	42.2	64.7	1.31	10.97	5.14	—
Wheat, hard, winter	89.4	13.5	11.3	79.6	1.61	0.05	0.42	—
Wheat, hard, spring	90.1	15.8	13.3	80.7	1.63	0.04	0.40	—
Wheat, soft, winter	89.2	10.2	8.6	80.1	1.62	—	0.29	[illegible]
Wheat, soft, Pacific Coast	89.1	9.9	8.3	79.9	1.61	—	[illegible]	—
Wheat bran	89.1	16.0	13.0	65.9	1.33	0.14	1.17	1.2
Wheat flour middlings	89.8	18.4	16.2	78.2	1.58	0.11	0.76	—

AVERAGE COMPOSITION AND DIGESTIBLE NUTRIENTS
(Continued)

Feedstuff	Total Dry Matter, %	Protein, %	Dig. Protein, %	TDN,[1] %	DE,[2] therms /lb	Calcium, %	Phosphorus, %	Carotene, mg/lb
			Concentrates—*Continued*					
Wheat germ oil meal	89.7	27.3	22.9	84.1	1.70	0.07	1.06	3.0
Wheat screenings, good grade	90.4	13.9	10.0	68.7	1.39	0.44	0.39	—
Wheat standard middlings	89.7	17.2	14.3	76.9	1.55	0.15	0.91	1.4
Whey, dried	93.5	13.1	11.8	78.4	1.58	0.87	0.79	—
Yeast, brewers dried	93.4	44.6	38.4	72.4	1.46	0.13	1.43	—
Yeast, torula, dried	93.3	48.3	41.5	69.9	1.41	0.57	1.68	—

[1] In calculating the values for total digestible nutrients, no digestion coefficients for a few feedstuffs were available, or the data were inadequate. In those instances the digestion coefficients for comparable feedstuffs were used.

[2] DE (digestible energy) may be converted to metabolizable energy by multiplying by 82 per cent.

The Committee on Animal Nutrition is indebted to Professor F. B. Morrison for the use of data from the 22nd Edition of *Feeds and Feeding* on the composition of roughages, silages, and cereals presented in this table. The data on the composition of by-product feeds were supplied by the Committee on Feed Composition of the National Research Council (NRC Pub. No. 449, 1956). The digestion coefficients used in calculating the digestible protein and TDN were also taken with Professor Morrison's permission from the 22nd Edition of *Feeds and Feeding*. These are based in part on the extensive compilation of digestion coefficients in *Feeds of the World* (W. Va. Agr. Exp. Sta., 1947), which was prepared by Dr. B. H. Schneider at the request of the Committee on Animal Nutrition.

COMPOSITION OF CALCIUM AND PHOSPHORUS SUPPLEMENTS

Mineral Supplement	Calcium, %	Calcium, gm/lb	Phosphorus, %	Phosphorus, gm/lb	Fluorine, %
Bone meal, raw, feeding	22.7	103	10.1	46	0.030
Bone meal, steamed	30.0	136	13.9	63	0.037
Defluorinated rock phosphate[1]	29.0	132	13.0	59	0.15 or less
Dicalcium phosphate	26.5	120	20.5	93	0.05
Limestone (high calcium)	38.3	174	nil	nil	—
Oyster shell flour	36.9	167	nil	nil	—

[1] High quality defluorinated rock phosphate should contain this amount of calcium and phosphorus and be no higher in fluorine than shown. For long time feeding to dairy animals, high quality products should be used.

Courtesy National Academy of Sciences—National Research Council.

ESTIMATED CAROTENE CONTENT OF FEEDS IN RELATION TO APPEARANCE AND METHODS OF CONSERVATION[1]

Feedstuff	Carotene, mg/lb
Fresh green legumes and grasses, immature	15 to 40
Dehydrated alfalfa meal, fresh, dehydrated without field curing, very bright green color[2]	110 to 135
Dehydrated alfalfa meal after considerable time in storage, bright green color	50 to 70
Alfalfa leaf meal, bright green color	60 to 80
Legume hays, including alfalfa, very quickly cured with minimum sun exposure, bright green color, leafy	35 to 40
Legume hays, including alfalfa, good green color, leafy	18 to 27
Legume hays, including alfalfa, partly bleached, moderate amount of green color	9 to 14
Legume hays including alfalfa, badly bleached or discolored, traces of green color	4 to 8
Non-legume hays, including timothy, cereal, and prairie hays, well cured, good green color	9 to 14
Non-legume hays, average quality, bleached, some green color	4 to 8
Legume silage	20 to 30
Green silage	5 to 20
Corn and sorghum silages, medium to good green color	2 to 10
Grains, mill feeds, protein concentrates, and byproduct concentrates, except yellow corn and its byproducts	.01 to 0.2

[1] This table was prepared by the late H. R. Guilbert, Davis, California.
[2] Green color is not uniformly indicative of high carotene content.
Courtesy National Academy of Sciences—National Research Council.

SUGGESTED CONCENTRATE MIXTURES FOR DAIRY ANIMALS

Roughage	Total protein in grain mixture, %	Ingredients,[1] lb			
		Corn	Oats	Wheat bran	Soybean oil meal
Legume hay or legume silage (alfalfa, clover, soybean, etc.)	12–14	400	300	300	—
Legume hay and corn or grass silage or mixed hay and silage	14–16	300	300	300	100
Mixed hay and silage	16	200	300	300	200
Grass hay and corn silage[2]	16–18	100	300	300	300

[1] It is recommended that 1% salt be added. In phosphorus-deficient areas, 1% of bonemeal or other fluorine-low phosphorus supplement should be added.

[2] Add 1% calcium carbonate or ground limestone.

National Academy of Sciences—National Research Council.

APPENDIX D

NEW ENGLAND COLLEGE CONFERENCE DAIRY GRAIN MIXTURES, 1959

20% DAIRY GRAIN MIXTURES

These mixtures are suggested as primarily for feeding with non-legume forage, especially the poorer grades.

Ingredients[a]	Quantity Standard formula (lb)	With urea[b] (lb)
Hominy and corn meal (or barley)[c]	600	900
Crimped or ground oats	300	200
Wheat bran	200	200
Corn distillers' grains (or corn gluten feed or brewers' dried grains)	200	200
Linseed oil meal (35%)	200	200
Soybean oil meal (44%)	500	200
Cane molasses	200	200
Urea (42% *N*)	—	45
Trace mineralized salt[d]	20	20
Dicalcium phosphate	—	20
Totals	2,220	2,185
Total digestible nutrients	73.5%	71.7%
Guaranteed Analysis:		
Protein—not less than	20%	20%
Fat—not less than	2.5%	3.0%
Fiber—not more than	8%	8%

[a] Because ingredients in parentheses were not used in calculating the guarantee, appropriate adjustments will have to be made if these ingredients are included. Such substitutions will tend to lower nutritive value.

[b] Care must be taken with formulas containing urea to assure thorough mixing. This can be done by adding the urea at the mid-point in the dumping of ingredients.

Regulations of the American Association of Feed Control Officials require that the following statement be included in the guarantee following the statement as to protein content: "This includes not more than 5.4% equivalent crude protein from non-protein nitrogen."

Also this statement should appear somewhere on the tag in large type: "Feeds containing urea are to be fed to ruminants only (cattle, sheep, and goats) and NOT to horses, swine, poultry, or other non-ruminating animals."

[c] Any combination of hominy and corn meal to make 600 (or 900) lb is considered satisfactory. The guarantee is based on the lowest combination of values for protein and fat and the highest combination of values for fiber.

NOTES FOR 20% DAILY GRAIN MIXTURES (*Continued*)

Barley may be substituted for part or all of either the hominy or the corn but not for more than half of the combined hominy-corn total because of possible lowering of palatability.

[d] A good commercial trace mineral mixture containing cobalt and iodine may be used with plain salt, or a mixture including phosphorous may be used to replace dicalcium phosphate and other trace minerals.

Note: Most of these formulas do not total a ton; that is so it will not be necessary to split bags of the major ingredients. Soybean oil meal containing 50% crude protein may be used in place of the 44% meal if proper adjustments are made in the mixtures.

16% DAIRY GRAIN MIXTURES

These mixtures are suggested for feeding with legume forage or the top grades of non-legume forage (early cut and well cured).

Ingredients[a]	Quantity: Standard formula (lb)	Quantity: With urea[b] (lb)
Hominy and corn meal (or barley)[c]	600	800
Crimped or ground oats	400	300
Wheat bran	300	200
Corn distillers' grains (or corn gluten feed or brewers' dried grains)	200	300
Linseed oil meal (35%)	100	100
Soybean oil meal (44%)	300	. . .
Cane molasses	200	200
Urea (42% N)	—	35
Trace mineralized salt[d]	20	20
Dicalcium phosphate	—	20
Totals	2,120	1,975
Total digestible nutrients	72.7%	71.6%
Guaranteed Analysis:		
Protein—not less than	16%	16%
Fat—not less than	3.0%	3.5%
Fiber—not more than	9%	8%

[a] Because ingredients in parentheses were not used in calculating the guarantee, appropriate adjustments will have to be made if these ingredients are included. Such substitutions will tend to lower nutritive value.

[b] Care must be taken with formulas containing urea to assure thorough mixing. This can be done by adding the urea at the mid-point in the dumping of ingredients.

Regulations of the American Association of Feed Control Officials require that the following statement be included in the guarantee following the statement as to protein content: "This includes not more than 4.7% equivalent crude protein from non-protein nitrogen."

NOTES FOR 16% DAIRY GRAIN MIXTURES (*Continued*)

Also this statement should appear somewhere on the tag in large type: "Feeds containing urea are to be fed to ruminants only (cattle, sheep, and goats) and NOT to horses, swine, poultry, or other non-ruminating animals."

[c] Any combination of hominy and corn meal to make 600 (or 800) lb is satisfactory. The guarantee is based on the lowest combination of values for protein and fat and the highest combination of values for fiber. Barley may be substituted for part or all of either the hominy or the corn but not for more than half of the combined hominy-corn total because of possible lowering of palatability.

[d] A good commercial trace mineral mixture containing cobalt and iodine may be used with plain salt, or a mixture including phosphorous may be used to replace dicalcium phosphate and other trace minerals.

14% DAIRY GRAIN MIXTURE

This mixture is intended for young stock, dry cows (both dairy and beef), and sheep. It can be used for milking cows where the forage is harvested early or contains a high percentage of legumes.

Ingredients[a]	Quantity (lb)
Hominy and corn meal (or barley)[b]	800
Crimped or ground oats	300
Wheat bran	300
Distillers' dried grains	200
Soybean oil meal (44%)	200
Cane molasses	200
Trace mineralized salt[c]	20
Dicalcium phosphate	15
D-activated plant sterol	4 oz[d]
Total	2,035
Total digestible nutrients	72.9%
Guaranteed Analysis:	
Protein—not less than	14%
Fat—not less than	3.0%
Fiber—not more than	8%

[a] Because the ingredient in parentheses was not used in calculating the guarantee, an appropriate adjustment will have to be made if this ingredient is included. Such a substitution will tend to lower the nutritive value.

[b] See footnote "c" under the 16% formula.

[c] See footnote "d" under the 16% formula.

[d] Based on usage of a concentrate containing 8 million units of vitamin D-2 per pound.

12% FITTING MIXTURE

This mixture is intended for young stock and dry cows (all on high-quality forage), milking cows on early pasture, and beef cattle.

Ingredients		Quantity (lb)
Hominy[a]		1,000
Crimped or ground oats		400
Wheat bran		200
Soybean oil meal (44%)		200
Cane molasses		200
Trace mineralized salt[b]		20
Dicalcium phosphate		15
D-activated plant sterol		4 oz[c]
	Total	2,035
Total digestible nutrients		74.5%
Guaranteed Analysis:		
Protein—not less than		12%
Fat—not less than		3.5%
Fiber—not more than		8%

[a] Ground or flaked barley may be substituted for not more than one-third of the hominy if price relationships are favorable.

[b] See footnote "d" under the 16% formula.

[c] See footnote "d" under 14% formula.

32% SUPPLEMENTS

These mixtures are intended for use with home-grown grains such as corn-and-cob meal or oats.

Ingredients[a]	Quantity Standard formula (lb)	Quantity With urea[b] (lb)
Soybean oil meal (44%)	1,000	500
Linseed oil meal (35%)	300	300
Wheat bran	200	300
Corn distillers' grains (or corn gluten feed or brewers' dried grains)	500	400
Hominy	—	200
Cane molasses	—	200
Urea (42% *N*)	—	70
Trace mineralized salt[c]	40	40
Dicalcium phosphate	30	30
Totals	2,070	2,040
Total digestible nutrients	74.6%	69.3%
Guaranteed Analysis:		
Protein—not less than	32%	32%
Fat—not less than	2.5%	2.5%
Fiber—not more than	9%	8%

[a] Because ingredients in parentheses were not used in calculating the guarantee, appropriate adjustments will have to be made if these ingredients are included. Such substitutions will tend to lower nutritive value.

[b] Care must be taken with formulas containing urea to assure thorough mixing. This can be done by adding the urea at the mid-point in the dumping of ingredients.

Regulations of the American Association of Feed Control Officials require that the following statement be included in the guarantee following the statement as to protein content: "This includes not more than 9.0% equivalent crude protein from non-protein nitrogen."

Also this statement should appear somewhere on the tag in large type: "Feeds containing urea are to be fed to ruminants only (cattle, sheep, and goats) and NOT to horses, swine, poultry, or other non-ruminating animals."

[c] A good commercial trace mineral mixture containing cobalt and iodine may be used with plain salt, or a mixture including phosphorous may be used to replace dicalcium phosphate and other trace minerals.

NOTES FOR 32% SUPPLEMENTS (*Continued*)

Proportions of home-grown grains to use for various levels of protein in the final mixture are:

	Corn-and-cob meal	Proportions of: 32% Supplement		Final mixture in pounds
For 14% protein	2 (67)	1 (33)	=	3 (100)
For 16% protein	3 (60)	2 (40)	=	5 (100)
For 20% protein	9 (45)	11 (55)	=	20 (100)
	Oats			
For 14% protein	9 (90)	1 (10)	=	10 (100)
For 16% protein	4 (80)	1 (20)	=	5 (100)
For 20% protein	3 (60)	2 (40)	=	5 (100)

The figures in parentheses are the amounts of each required for 100 pounds of the final mixture.

CALF STARTER

Ingredients	Quantity (lb)
Corn (coarse ground)	700
Standard wheat middlings	300
Distillers' dried corn solubles	200
Dried skim milk	50
Crimped oats	200
Soybean oil meal (44%)	400
Cane molasses	100
Trace mineralized salt[a]	20
Dicalcium phosphate	20
Vitamin A and D dry supplement[b]	5
Antibiotic feed supplement[c]	28
Total	2,023
Total digestible nutrients	74%
Guaranteed Analysis:	
Protein—not less than	18%
Fat—not less than	3%
Fiber—not more than	6%

[a] A good commercial trace mineral mixture containing cobalt and iodine may be used with plain salt, or a mixture including phosphorous may be used to replace dicalcium phosphate and other trace minerals.

[b] A dry mix containing at least 3000 International Units of vitamin A (or 2 milligrams of carotene) and 500 units of vitamin D-2 per gram.

[c] Amount of supplement if Aurofac is used. Terramycin or bacitracin may be used according to manufacturers instructions.

The foregoing grain mixtures when fed with good quality forage will normally supply all the necessary minerals and vitamins. However, when

CALF STARTER (*Continued*)

heifers and milking cows are fed little or no grain and the forage contains little or no legumes, added minerals may be desirable. In such cases a mineral mixture consisting of two parts of dicalcium phosphate to one part of trace mineralized salt may be offered free choice.[a] It should be protected from leaching by rain. Trace mineralized salt blocks also may be supplied either in the barn or on pasture. These recommendations do not apply to sheep; there is some evidence that such mixtures may be the cause of urinary calculi (kidney stone) in sheep, especially in young lambs. Sheep should get their salt supply from salt alone, not from a mineral mixture.

Recent research has shown that feeds ground to a medium degree of fineness generally are more completely digested by the dairy cow than coarse-textured feeds, although crimped oats are digested as completely as ground oats of equal quality. Although coarse-textured feeds generally are consumed a little more quickly, high-quality "fine" feeds usually are consumed in as large amounts. There appears, therefore, to be no real advantage in most cases in providing milking cows with coarse-textured feeds, unless dustiness is a problem in "fine" feeds where molasses is not used.

Where not already included, a vitamin A supplement is recommended for all the foregoing formulas during the latter half of the winter feeding period if silage is not fed, especially if hay is of poor quality. Recommended rate and form is one pound of dry stabilized vitamin A supplement per ton of feed.

MILK REPLACER FOR CALVES

Ingredients	Quantity (lb)
Dried skim milk	500
Dried whey or whey product	500
Dextrose (corn sugar)	170
Oat flour	300
Brewers' dried yeast	150
Distillers' dried solubles	300
Antibiotic[b]	20
Vitamin A and D supplement[c]	10
Iodized salt	20
Mineral mixture[a]	30
Total	2,000
Total digestible nutrients	75.5%
Guaranteed Analysis:	
Protein—not less than	20%
Fat—not less than	2%
Fiber—not more than	2%

[a] The mineral mixture on page 419 or a good commercial trace mineral mixture containing cobalt and iodine may be used with plain salt or a mixture including phosphorous may be used to replace dicalcium phosphate and other trace minerals.

MILK REPLACER FOR CALVES (*Continued*)

[b] Amount of supplement if Aurofac is used. Terramycin or bacitracin according to manufacturer's recommendations.

[c] In dry form: containing at least 5000 I.U. units of vitamin A and 500 I.U. units of vitamin D per gram.

MINERAL MIXTURE TO BE USED IN MILK REPLACER

Ingredients	Quantity
Dicalcium phosphate	98 lb
Ferrous sulfate	1 lb
Copper sulfate	½ lb
Cobalt sulfate	1 oz
Total	99½ lb plus the ounce of cobalt

A good commercial mineral mixture may be used in place of the above.

Start feeding milk replacer when the calf is 4 days old; replace whole milk gradually (a quart at a time) with the milk substitute during the next four days. Discontinue whole milk entirely at 7 or 8 days of age. Then feed milk replacer twice daily at the rate of one-half pound of the reconstituted liquid for each 10 lb of body weight, but not more than 10 lb daily.

Prepare by mixing one level cupful with one quart of water at body temperature, taking care that it does not lump.

Teach the calf to eat the cheaper calf starter as early as possible. (4th or 5th day.) Placing a small amount in the calf's mouth or in the bottom of the pail when it finishes drinking helps to get it started. Decrease the milk replacer after 4 weeks, at the same time increasing the amount of calf starter. The calf should be completely weaned from milk replacer by the time it is 7 weeks old.

Success in calf raising depends on careful management and strict sanitation, as well as on a good feeding program.

HOW TO FORMULATE A MIXTURE CONTAINING A CERTAIN PERCENTAGE OF PROTEIN

Often it is useful to know how to calculate a ration with a given percentage of protein. The example below shows how this can be done.

A 15% mixture is wanted. The various ingredients are decided upon, leaving, for example, the protein supplement and oats until the last. By varying the amounts of supplement and oats we can therefore get a 15% mixture. Let's assume we have selected 1600 lb of ingredients. By totaling the protein in each of the ingredients we have 208 lb of protein or 13%. How much 32% supplement and how many pounds of oats (protein 12%) must be used to get the 15% desired?

As seen, we already have 208 lb of protein. We need 300 lb (15% × 2000 lb) or 92 lb more. We must get the 92 lb of protein from 400 lb of grain (2000 −

HOW TO FORMULATE A MIXTURE CONTAINING A CERTAIN PERCENTAGE OF PROTEIN (*Continued*)

1600 = 400). Dividing 92 lb of protein by 400, we see that the 400 lb to be added will have to average 23% protein.

$$400\overline{)\,92.\,}^{\;.23}$$

The problem is solved by the "square" method as follows:

(Supp) 32%		11 (23 minus 12)
	23%	
(Oats) 12%		9 (32 minus 23)
		20

By adding 11 and 9 we see that there are 20 "portions." Looking across from 32% we see that 11 parts (of the 20) must be the 32%. Looking across from the oats we see that 9 parts are oats.

$$\frac{11}{20} \times 400 = 220 \text{ lb supplement}$$

$$\frac{9}{20} \times 400 = 180 \text{ lb oats}$$

To check our answer:

$$\begin{aligned} 220 \times 32\% &= 70.4 \\ 180 \times 12 \quad &= \underline{21.6} \\ & \ 92.0 \text{ lb protein} \end{aligned}$$

The mixture, to make 15% protein, must have 220 lb of 32% supplement and 180 lb of oats, added to the 1600 lb of other ingredients to make one ton.

With only two ingredients the procedure is somewhat simpler. If, for example, we have corn-and-cob meal on hand and we wish to know what proportions of it and of soybean meal to use in order to get a ton of 16% protein mixture, we would set up the square in this manner:

Soybean oil meal (44%)		16 − 7 = 9
	16%	
Corn-and-cob meal (7%)		44 − 16 = 28
		37

From the above we see that a 16% protein mixture requires 28 parts of corn-and-cob meal to 9 parts of soybean oil meal, which makes a total of 37 parts. There are just a fraction over 54 such parts in a ton—

$$\frac{2000}{37} = 54.05 \text{ (Call it 54 for easy reckoning).}$$

Multiplying each part by 54, we find that we need:

$$\begin{aligned} 9 \times 54 &= 486 \text{ lb of soybean oil meal} \\ 28 \times 54 &= \underline{1512} \text{ lb of corn-and-cob meal} \\ \text{Total} \quad &= 1998 \text{ lb of } 16\% \text{ mixture} \end{aligned}$$

Add one pound of each to make the even ton.

APPENDIX E

FEEDING TABLES

POUNDS OF GRAIN DAILY FOR BARN-FED COWS

Per cent butterfat	3.5%			4%			5%			5.5%		
	Quality			Quality			Quality			Quality		
Type of Forage	High	Good	Low	High	Good	Low	High	Good	Low	High	Good	Low
Daily Milk Production: 5 lb			2			2			3			4
10 lb			3			4		2	6		3	7
15 lb		2	5	1	3	6	2	5	8	2	6	9
20 lb	2	4	7	2	5	8	4	7	11	5	8	12
25 lb	4	6	9	4	7	10	6	10	13	7	11	15
30 lb	6	8	11	6	9	12	9	12	16	10	14	17
35 lb	8	10	13	8	11	14	11	15	18	13	16	20
40 lb	10	12	15	11	14	17	14	17	21	15	19	23
45 lb	12	14	17	13	16	19	16	20	23	18	22	—
50 lb	14	16	19	15	18	21	19	22	—	21	—	—
55 lb	16	18	21	17	20	23	21	—	—	23	—	—
60 lb	18	20	23	19	22	—	24	—	—	—	—	—

No cow should be fed more grain than she can handle safely.
Heavy producing cows must be fed individually.
Dry cows should be fed 2 to 8 lb of grain daily depending on their condition.

POUNDS OF GRAIN DAILY FOR COWS ON PASTURE

Per cent butterfat	3.5%			4%			5%			5.5%		
	Quality			Quality			Quality			Quality		
Type of Forage	High	Good	Low	High	Good	Low	High	Good	Low	High	Good	Low
Daily Milk Production												
5 lb									1			2
10 lb			2			2			3			4
15 lb			3			4		1	6		2	7
20 lb		2	5		2	6		4	8	1	5	9
25 lb		4	7	1	4	8	2	6	11	3	7	12
30 lb	2	6	9	2	6	10	4	9	13	5	10	15
35 lb	4	8	11	5	8	12	7	11	16	8	13	17
40 lb	6	10	13	7	11	14	9	14	18	10	15	20
45 lb	8	12	15	9	13	17	12	16	21	13	18	—
50 lb	10	14	17	11	15	19	14	19	—	16	21	—
55 lb	12	16	19	13	17	21	17	21	—	18	—	—
60 lb	14	18	—	15	19	—	19	—	—	21	—	—
65 lb	16	20	—	17	21	—	21	—	—	—	—	—

No cow should be fed more grain than she can handle safely.
Heavy producing cows must be fed individually.
Dry cows may need 2 to 5 lb of grain daily while on pasture.

APPENDIX F

TESTS FOR VARIOUS DAIRY PRODUCTS

Kohman Analysis of Butter

This is a simple, rapid, and reasonably accurate test for plant and laboratory control of butter. The percentage of moisture, butterfat, salt, and curd is determined in the analysis.

A sample of butter is taken from the churn, tub, or print of butter in a dry cup or beaker. Warm the sample slightly and work it with a spatula until it is uniform throughout. Then weigh 10 grams of the butter into a weighed or tared aluminum dish and proceed as follows:

1. *Moisture.* Dry the sample to constant weight over a flame or on a hot plate. Cool the sample, weigh, and calculate the moisture content.

2. *Fat.* Add about 100 ml of high-test gasoline or petroleum ether to the residue. Stir thoroughly with a stirring rod, then allow to settle for 5 minutes. Decant the fat solution carefully so that none of the residue is lost. Wash again with the solvent, stir, and allow to settle for 5 minutes. Again pour off the solvent carefully. By careful heating, dry the residue and reweigh.

The difference between this weight and the previous one represents the fat. Calculate the per cent fat.

3. *Salt.* To the residue remaining add hot water in portions until the salt is entirely removed. Save the washings and bring to 250 ml. Titrate 25 ml with silver nitrate, using potassium chromate as an indicator. If the silver nitrate solution contains 14.525 grams per liter, the burette reading divided by 2 equals the per cent salt.

4. *Curd.* Curd is determined by difference. Subtract the total of the previous determinations from 100 to get the per cent curd. It may also be determined by subtracting the per cent salt from the weight of the material left after extracting the fat. That residue is salt and curd.

The American Association Test for Buttermilk

Normal butyl alcohol and commercial sulfuric acid (sp. gr. 1.82-1.83) are used.

1. Add the chemicals and buttermilk to the test bottle in the following amounts and the order indicated: (*a*) 2 ml of *n*-butyl alcohol; (*b*) 8.8 ml of buttermilk; (*c*) 7 to 9 ml of sulfuric acid, depending on its strength. The right amount is being used when the butterfat column is golden yellow.
2. Mix contents of bottle thoroughly.
3. Centrifuge for 6 minutes at the proper speed.
4. Add hot water to fill the bottle to the base of the neck and whirl 2 minutes.
5. Add hot water to bring the butterfat into the neck, and again whirl 2 minutes.
6. Temper to 135° to 140° F and read. Double the reading to obtain the per cent of butterfat.

The Minnesota Test for Buttermilk

The reagent known as the Minnesota-Babcock Test Reagent is made up as follows:

110 grams sodium carbonate
200 grams sodium salicylate

Dissolve in distilled water and make up the volume to 1,000 ml.

To this solution add 30 ml of 50 per cent NaOH and 100 ml of *n*-butyl alcohol.

The procedure in making the test is as follows:

1. 8.8 ml buttermilk in a skim-milk test bottle.
2. 10 ml of above reagent.
3. Mix thoroughly.
4. Place in water bath at 160–180° F for 6 minutes. Shake several times during this interval.
5. Centrifuge for 5, 2, and 1 minutes.
6. Temper at 140° F.
7. Read.

The Mojonnier Test for Butterfat in Ice Cream

Mix the sample very thoroughly, and if necessary heat it slightly in order to melt the butterfat. If the sample is not homogeneous, great care must be exercised in weighing it out; otherwise the accuracy of the results will be affected. Weigh the sample, using either the weighing cross or the weighing pipettes, and, if the sample is not homo-

geneous, weigh it directly into the extraction flask suspended from the balance arm. Use a sample of about 5 grams.

For the first extraction, add 5 ml of water, 1.5 ml of ammonia, 10 ml of alcohol, and 25 ml each of ethyl and petroleum ethers. Shake thoroughly after adding water, and again after adding the ammonia, and one-half minute each after adding the alcohol and the two ethers.

Centrifuge 30 turns, taking ½ minute.

For the second extraction add neither water nor ammonia. Add 5 ml of alcohol, 25 ml each of ethyl and petroleum ethers, and shake 20 seconds after the addition of each reagent.

Centrifuge 30 turns, taking ½ minute.

If necessary to raise the dividing line, add the necessary distilled water just before pouring off the ether solution.

After evaporating off the ether, heat the dish with the butterfat, in the vacuum oven at 135° C for 5 minutes with not less than 20 in. of vacuum. Cool in the cooling desiccator at room temperature for 7 minutes.

Weigh rapidly. Record results and calculate the percentage of butterfat.

The Mojonnier Test for Butterfat in Unsweetened Condensed Milks

Unsweetened condensed milk or evaporated milk, whether unsterilized or sterilized, is all tested for butterfat in very much the same manner. Superheated plain bulk condensed is difficult to sample properly, so that great care must be exercised in getting representative samples. Evaporated milk sterilized in the can, especially after standing for a considerable time, sometimes contains the butterfat either separated in the form of cream or in the form of churned butterfat. Samples in this condition are difficult to test, and the proper allowance should always be made in such cases.

To weigh the sample use either the weighing cross or the weighing pipettes; in some cases it may be desirable to weigh directly into the flask suspended from the balance arm. The last method would apply where the samples are not homogeneous. Use a sample of about 5 grams, excepting in the case of condensed buttermilk and of extra-heavy superheated milk, when only 3 grams should be used.

For the first extraction, add 4 ml of water (except in the case of condensed buttermilk and of extra-heavy superheated milk, when 6 ml of water should be used). Use 1.5 ml of ammonia, 10 ml of alcohol, and 25 ml each of ethyl and petroleum ethers. Shake thoroughly after the

addition of water; again after adding the ammonia; ½ minute after the addition of the alcohol and 20 seconds after the addition of each of the two ethers.

Centrifuge 30 turns, taking ½ minute.

For the second extraction, add neither water nor ammonia. Add 5 ml of alcohol, 25 ml each of ethyl and petroleum ethers, and shake 20 seconds after the addition of each reagent. (In the case of plain condensed skim milk, and condensed buttermilk, use only 15 ml of each ether in the second extraction.)

Centrifuge 30 turns, taking ½ minute.

If necessary to raise the dividing line, add the necessary distilled water just before pouring off the ether solution in the second extraction.

After evaporating off the ether, heat the dish with the fat in the vacuum oven at 135° C for 5 minutes with not less than 20 inches of vacuum. Cool in the cooling desiccator to room temperature for 7 minutes.

Weigh rapidly. Record results and calculate the percentage of butterfat.

The Mojonnier Test for Solids in Ice Cream

To weigh the sample, use either the weighing cross or the weighing pipette, or weigh the sample directly into the dish upon the balance pan. In any case, use about 1-gram sample. Add 1 ml of water. Spread the ice-cream mix with the added water in a thin film over the entire bottom of the dish. Now place the dish in direct contact upon the outside hot plate having a temperature of 180° C, and heat the dish until the first traces of brown begin to appear in the residue. Transfer the dish to the vacuum oven for 10 minutes under not less than 20 inches of vacuum. Transfer to the cooling desiccator, and hold it there for 5 minutes with the water-circulating pump operating continuously. Weigh rapidly. Record weights and calculate the percentage of total solids.

Nebraska Ice-Cream Butterfat Test

The reagents used in this test are made up as follows:

Reagent A. 9 parts *n*-butyl alcohol and 1 part C.P. ammonium hydroxide mixed together (both by volume).

Reagent B. 1 part commercial sulfuric acid (1.82-1.83 sp. gr.) and 1 part ethyl alcohol (95 per cent) (both by volume).

The test is made as follows:

1. Melt sample of ice cream in a closed jar; mix thoroughly.

2. Weigh 9 grams into a 10 per cent milk test bottle.

3. Add 5 ml of reagent A and mix.

4. Add 30 ml of reagent B (cooled to room temperature before using) and mix.

5. Hold in a water bath at 175° to 180° F for 15 minutes, shaking at least 3 times during this period.

6. Centrifuge 5, 2, and 1 minutes. If curd is present shake after the first and second whirlings. Water is added as in the regular Babcock test.

7. Place in a water bath at 135° to 140° F for 5 minutes.

8. Add glymol and read.

PREPARATION OF SOLUTIONS

Sodium Hydroxide Solutions for the Acid Test

Normal solutions, as a general rule, are prepared so that 1 liter shall contain the hydrogen equivalent of the active reagent weighed in grams (Sutton). Caustic soda (NaOH) is made up of an atom of sodium (Na), oxygen (O), and hydrogen (H); its molecular weight is therefore

$$\underset{\text{Na}}{23} + \underset{\text{O}}{16} + \underset{\text{H}}{1} = 40$$

A normal NaOH solution then is made by dissolving 40 g of NaOH in water, making up the volume to 1,000 ml; a $0.1N$ solution will contain one-tenth of this amount of NaOH, or 4 g dissolved in 1 liter. One milliliter of the latter solution will contain 0.004 g of NaOH, and will neutralize 0.009 g of lactic acid. The formula for lactic acid is $C_3H_6O_3$, and its molecular weight is therefore $[(3 \times 12) + 6] + (3 \times 16) = 90$. A $0.1N$ solution of lactic acid contains 9 g per liter, and 0.009 g per milliliter.

Sodium Hypochlorites and Chloramine-T Solutions

A solution of any strength can be prepared by simply adding the necessary amount of the sterilizer to a given amount of water. The amount to be added can be calculated as follows:

Divide the percentage of active chlorine in the sterilizer by the number of parts of chlorine per million parts of water desired in the solution, then multiply the quotient by 10,000. The product obtained indicates the number of ounces of water to be used for each ounce of sterilizer. Any other unit of weight can be substituted for the ounce.

To illustrate: A solution is to be prepared which will have 50 parts of chlorine in 1 million of water, a commercial product being used which contains 2.5 per cent chlorine:

$$2.5 \div 50 = 0.05$$

Then $0.05 \times 10{,}000 = 500$ (ounces of water to 1 oz of sterilizer). Hence, to make a solution the strength of which is to be 50 parts of active chlorine in 1 million parts of water, from a sterilizer containing 2.5 per cent of active chlorine, it is necessary to use 1 oz of the sterilizer to 500 oz of water.

AVERAGE COMPOSITION AND WEIGHTS PER GALLON OF INGREDIENTS USED IN ICE-CREAM MIX

	Per Cent Butter-fat	Per Cent Milk S.N.F.	Per Cent Sugar	Per Cent Total Solids	Weight per Gallon, Pounds
Water	0.00	0.00	0.00	0.00	8.3
Skim milk	0.00	8.91	0.00	8.91	8.6
Milk	3.00	8.33	0.00	11.33	8.6
Milk	4.00	8.79	0.00	12.79	8.6
Milk	5.00	9.10	0.00	14.10	8.6
Cream	12.00	7.80	0.00	19.80	8.5
Cream	15.00	7.57	0.00	22.57	8.5
Cream	18.00	7.31	0.00	25.31	8.5
Cream	20.00	7.13	0.00	27.13	8.5
Cream	25.00	6.68	0.00	31.68	8.4
Cream	30.00	6.24	0.00	36.24	8.4
Cream	35.00	5.69	0.00	40.79	8.4
Cream	40.00	5.35	0.00	45.35	8.3
Evaporated milk, canned	8.00	20.00	0.00	28.00	8.9
Evaporated milk, bulk	10.00	23.00	0.00	33.00	9.2
Sweetened condensed whole milk	8.00	23.00	42.00	73.00	9.2
Skim condensed (unsweetened)	0.00	26.70	0.00	26.70	9.2
Skim condensed (sweetened)	0.00	26.70	42.00	68.70	9.2
Skim-milk powder	0.00	97.00	0.00	97.00	
Whole-milk powder	26.00	72.00	0.00	98.00	
Granulated sugar	0.00	0.00	100.00	100.00	7.5
Invert sugar syrup	0.00	0.00	71.50	71.50	10.0
Corn sugar	0.00	0.00	0.00	90.00	
Corn syrup	0.00	0.00	82.00	82.00	
Gelatin or ice-cream powder	0.00	0.00	0.00	90.00	
Butter, unsalted	84.00	1.00	0.00	85.00	
Butter, oil	100.00	0.00	0.00	100.00	7.5
Dried egg yolk	50.00	0.00	0.00	95.00	
Fluid egg	9.90	0.00	0.00	25.70	1.5 lb per doz.

SOME CUSTOMARY WEIGHTS AND MEASURES AND THEIR EQUIVALENTS

Weights

1 oz	=	28.35 g
1 lb	=	453.6 g
1 g	=	0.035274 oz
1 kg	=	2.2046 lb

Dry Measures

3 teaspoonfuls (tsp)	=	1 tablespoonful (tbsp)
1 heaping tsp. sugar	=	1 oz
1 heaping tsp. gelatin	=	1 oz
2 tbsp flour	=	1 oz
2 tbsp coffee	=	1 oz
2 cups sugar	=	1 lb

Liquid Measures

1 qt milk	=	2.15 lb
1 oz	=	29.57 ml
1 qt	=	946.5 ml
1 liter	=	1,000 ml
1 liter	=	1.0567 qt
1 ml	=	15 to 20 drops
4 tsp	=	1 tbsp
1 tbsp	=	½ oz
32 oz	=	1 qt
16 tbsp	=	1 cup
2 cups	=	1 pt

FEDERAL AND STATE STANDARDS FOR THE COMPOSITION OF MILK PRODUCTS

(U.S.D.A. AGRICULTURE HANDBOOK, NO. 51, SEPTEMBER, 1956)

	Whole Milk, min. %			Skim Milk,[25] min. %		Nonfat, Fat Free Defatted Milk, min. %		Cultured Buttermilk, min. %	Chocolate Milk, min. %	Chocolate Drink, min. %
	Milk Fat	Milk Solids not Fat	Total Milk Solids	Milk Solids not Fat	Total Milk Solids	Milk Fat	Milk Solids not Fat	Milk Solids not Fat	Milk Fat	Milk Fat
Federal	...	...	...	...	...	...	...	...	...	...
Alabama	3.25	8.5	11.75	8.50	...	...	...	8.50	3.0	2.0
Alaska	3.25	8.25	11.50	8.25	...	...	...	8.25	3.25	
Arizona	3.50	8.0	11.5	8.0	...	...	...	...	3.5	.
Arkansas	3.25	8.0	11.25	...	...	...	...	8.0	3.25	
California	3.5	8.15	...	8.5	...	0.25	8.5	(1)	3.5	
Colorado	3.2	8.25	...	8.25	...	.1	...	8.25	3.2	...
Connecticut	3.25	8.25	...	(2)	...	...	...	8.0	3.25	...
Delaware	3.5	8.5	...	8.5	...	...	...	8.5	3.5	2.0
District of Columbia	3.5	...	11.5	...	9.0	...	...	...	3.5	...
Florida	3.25	8.5	...	8.5	...	...	...	8.5	2.0	(3)
Georgia	3.25	8.5	11.75	...	9.25	...	...	8.5	3.25	2.0
Hawaii	[4]3.0	8.5	...	8.5	...	...	...	8.5	[4]3.0	...
Idaho	3.2	8.0	11.0	...	9.3	...	...	(5)	(5)	(5)
Illinois	3.0	8.5	11.5	...	9.25	.5	8.0	...	3.0	...
Indiana	3.25	8.0	...	...	8.5	...	...	8.0	3.0	
Iowa	3.25	...	11.5	...	11.5	...	...	...	...	
Kansas	3.25	[6]8.25	...	[6]8.25	...	[6].1	...	[6]8.25	[6]3.25	
Kentucky	3.25	8.0	...	...	...	...	...	8.5	3.25	
Louisiana	3.8	8.5	12.3	8.5	...	...	...	8.5	3.8	
Maine	3.25	...	11.75	...	...	[7].1	...	[7]8.5	[7]3.25	
Maryland	3.5	...	12.0	...	...	.1	...	8.25	2.5	
Massachusetts	[8]3.35	...	[8]12.0	9.3	...	...	...	8.5	3.35	.
Michigan	[9]3.0	8.5	...	8.5	...	...	...	8.5	3.0	3.0
Minnesota	3.25	...	...	...	...	.1	...	[10]8.25	3.25	...
Mississippi	3.5	8.25	11.5	8.25	...	...	...	8.25	3.5	
Missouri	3.25	8.0	...	8.0	...	...	...	8.0	3.25	
Montana	3.25	8.25	11.5	8.25	...	.1	...	8.25	3.25	
Nebraska	[11]3.0	[12]8.25	...	...	9.25	[12].1	...	[12]8.25	[11]3.0	.
Nevada	3.25	8.5	11.5	8.5	...	...	...	8.0	[13]3.25	
New Hampshire	[14]3.35	...	11.85	8.5	...	...	...	8.5	3.35	...
New Jersey	[15]3.0	...	[15]11.5	...	...	.5	...	...	...	...
New Mexico	3.25	8.0	...	8.0	...	...	...	8.0	3.25	...
New York	3.0	...	11.5	...	8.5	...	...	...	3.0	...
North Carolina	[16]3.6	8.25	...	8.25	...	...	...	8.25	3.25	2.0
North Dakota	3.25	...	11.5	8.5	...	...	...	8.5	(17)	(17)
Ohio	[18]3.0	...	12.0	...	...	...	...	8.0	3.5	(19)(20)
Oklahoma	3.25	[21]8.0	...	8.0	...	...	...	[21]8.0	3.25	
Oregon	3.2	8.5	11.7	8.5	...	.5	8.5	8.5	3.2	...
Pennsylvania	3.25	...	12.0	...	...	...	...	...	2.5	
Puerto Rico	3.0	9.0	12.0	...	...	...	...	...	...	
Rhode Island	[22]3.25	[10]8.25	11.5	8.25	...	.1	...	8.25	3.25	...
South Carolina	3.8	8.0	11.8	8.0	...	...	...	...	2.0	2.0
South Dakota	3.25	8.25	...	...	9.25	.1	...	8.25	3.25	...
Tennessee	3.5	8.5	12.0	8.5	...	...	...	8.5	3.5	
Texas	3.25	8.0	...	8.0	...	.1	...	8.5	3.25	...
Utah	3.2	8.3	11.5	8.5	...	.1	...	8.25	3.2	...
Vermont	3.5	8.5	...	8.5	...	...	...	...	3.5	...
Virginia	3.25	8.5	11.75	8.5	...	...	...	8.0	3.25	...
Washington	3.5	8.25	...	8.8	...	0.25	...	8.25	3.5	.
West Virginia	3.0	8.5	11.5	...	9.0	...	...	8.0	3.0	
Wisconsin	[23]3.0	8.25	...	...	8.5	.25	...	8.25	3.0	
Wyoming	3.25	8.25	...	8.25	...	[24].25	...	8.25	[24]3.25	

[1] Total milk solids, not less than 8.0%. [2] Grade A, milk fat, not more than 0.5%. [3] Milk fat, not more than 1.0%. [4] Grade AA, milk fat, not less than 3.25%. [5] Follow U.S. Public Health Ordinance and Code. [6] Grade A regulation effective April 1, 1956. [7] Effective May 1, 1956. [8] Grade A, milk fat, not less than 4%; total milk solids not less than 12.2%. [9] Pasteurized, milk fat, not less than 3.5%. [10] Grade A, milk solids not fat, not less than 8.5%. [11] Grade A, milk fat, not less than 3.25%. [12] Grade A requirement only. [13] Advisory Standard. [14] Grade A, milk fat, not less than 3.7%. [15] When labeled "New Jersey Grade A Pasteurized" milk fat not less than 4.0%; total milk solids, not less than 12.75%. [16] Market fluid milk only. [17] Must contain not less than 90% of milk. [18] Standardized milk, milk fat, not less than 3.5%. [19] Milk fat, not more than 2.0%. [20] Chocolate Dairy Drink, milk fat, not less than 2.0%. [21] Grade A, milk solids not fat, not less than 8.25%. [22] Grade A, milk fat, not less than 3.5%. [23] Standardized milk; milk fat, not less than 3.25%. [24] Grade A only. [25] Milk fat, less than amount required for whole milk.

FEDERAL AND STATE STANDARDS (Continued)

	Half and Half, min. %	Cream, min. %					Evaporated Milk, min. %		Sweetened Condensed (Whole) Milk, min. %	
		Light	Medium	Whipping	Heavy Whipping	Cultured Sour				
	Milk Fat	Milk Fat	Milk Fat	Milk Fat	Milk Fat	Milk Fat	Milk Fat	Total Milk Solids	Milk Fat	Total Milk Solids
Federal	...	18.0	...	30.0	36.0	...	7.9	25.9	8.5	28.0
Alabama	10.0	18.0	...	30.0	...	...	7.8	25.5	8.0	28.0
Alaska	11.5	18.0	...	30.0	36.0	18.0	(1)	(1)	(1)	(1)
Arizona	11.0	18.0	...	...	...	18.0	7.9	25.9	8.5	28.0
Arkansas	11.0	18.0	...	(1)	(1)	...	7.9	25.9	8.0	28.0
California	11.7	20.0	...	[2]35.0	...	20.0	7.9	25.9	8.5	28.0
Colorado	11.0	18.0	...	30.0	36.0	18.0	7.7	...	7.7	28.0
Connecticut	12.0	16.0	26.0	...	36.0	12.0	7.9	25.9	8.5	28.0
Delaware	11.5	18.0	...	...	...	...	...	...	...	...
District of Columbia	11.75	20.0	...	...	...	...	(1)	(1)	(1)	(1)
Florida	[3]10.0	18.0	...	...	...	...	7.8	25.5	8.0	28.0
Georgia	11.5	18.0	...	35.0	...	...	(1)	(1)	(1)	(1)
Hawaii	...	18.0	...	30.0	...	18.0	(1)	(1)	(1)	(1)
Idaho	(4)	18.0	...	(4)	(4)	...	(1)	(1)	(1)	(1)
Illinois	10.5	18.0	...	30.0	...	18.0	7.9	25.9	8.5	28.0
Indiana	...	(1)	...	(1)	(1)	18.0	(1)	(1)	(1)	(1)
Iowa	...	16.0	...	...	...	...	...	...	...	...
Kansas	[5]11.5	18.0	...	[5]30.0	...	...	7.8	25.5	8.0	28.0
Kentucky	...	18.0	...	30.0	...	...	7.8	25.5	8.0	28.0
Louisiana	11.5	18.0	...	30.0	...	18.0	7.9	25.5	8.0	28.0
Maine	...	18.0	30.0	...	38.0	...	[6]7.9	[6]25.9	[6]8.5	[6]28.0
Maryland	12.0	18.0	...	...	36.0	...	(1)	(1)	(1)	(1)
Massachusetts	[7]10.0	16.0	25.0	...	[8]34.0	...	7.8	...	8.0	...
Michigan	10.0	18.0	...	30.0	...	...	(9)	(9)	...	...
Minnesota	12.0	20.0	...	30.0	36.0	20.0	7.9	25.9	8.5	28.0
Mississippi	11.5	18.0	...	(1)	(1)	18.0	7.8	25.5	8.0	28.0
Missouri	11.5	18.0	...	30.0	...	...	[10]7.9	[10]25.9	8.0	28.0
Montana	11.5	18.0	...	30.0	36.0	...	7.8	25.5	8.0	28.0
Nebraska	[12]10.5	18.0	...	[11]30.0	[11]36.0	18.0	(1)	(1)	(1)	(1)
Nevada	12.0	22.0	...	30.0	36.0	...	7.9	25.9	8.5	28.0
New Hampshire	...	18.0	...	...	36.0	...	7.9	25.9	8.5	28.0
New Jersey	...	16.0	...	...	[11]36.0	16.0	[13]7.8	[13]25.5	8.0	28.0
New Mexico	...	18.0	...	...	...	...	[13]7.8	[13]25.5	8.0	28.0
New York	10.0	18.0	25.0	...	36.0	...	7.8	25.5	8.0	28.0
North Carolina	10.0	18.0	...	30.0	36.0	...	[13]7.8	[13]25.5	8.0	28.0
North Dakota	...	20.0	...	30.0	36.0	...	7.9	25.9	8.5	28.0
Ohio	10.75	18.0	...	30.0	...	...	7.9	25.9	8.5	28.0
Oklahoma	[11]11.5	18.0	...	30.0	36.0	[11]18.0	7.9	25.9	8.5	28.0
Oregon	10.0	18.0	...	30.0	...	18.0	7.9	25.9	...	...
Pennsylvania	...	18.0	...	36.0	...	...	7.8	[13]25.5	8.0	28.0
Puerto Rico	...	18.0	...	...	...	...	...	...	...	...
Rhode Island	11.5	18.0	25.0	30.0	36.0	...	7.8	25.5	8.0	28.0
South Carolina		18.0		...	...	...	...	...	...	...
South Dakota	11.5	18.0		30.0	36.0	18.0	[13]7.8	[13]25.5	8.0	28.0
Tennessee	11.5	18.0	...	30.0		18.0	7.8	25.5	8.0	28.0
Texas	11.5	18.0	...	30.0	36.0	...	7.9	25.9	8.5	28.0
Utah	11.5	18.0	...	30.0	...	...	7.8	25.5	(1)	(1)
Vermont	[14]12.0	18.0	25.0	...	35.0	...	(1)	(1)	(1)	(1)
Virginia	11.0	18.0	...	(1)	(1)	...	(1)	(1)	(1)	(1)
Washington	11.5	20.0	...	30.0	...	20.0	7.9	25.9	...	28.0
West Virginia		18.0	...	30.0	(1)	...	7.8	25.5	7.8	28.0
Wisconsin	12.0	18.0	...	30.0	...	18.0	7.9	25.9	8.0	28.0
Wyoming	12.0	18.0	...	30.0	..	...	7.9	25.9	7.9	25.9

[1] Follow Federal Food and Drug Standards.
[2] Pastry cream, milk fat, not less than 30%.
[3] Milk fat, not more than 12%; added milk-solids-not-fat, not more than 2%.
[4] Follow U. S. Public Health Ordinance and Code.
[5] Grade A regulation, effective April 1, 1956.
[6] Effective May 1, 1956.
[7] Effective February 10, 1956.
[8] Extra heavy cream, milk fat not less than 38%.
[9] Must meet the requirements for milk when reconstituted according to directions on the label.
[10] The sum of the percentages of milk fat and total milk solids shall not be less than 33.8%.
[11] Grade A requirement only.
[12] Grade A, milk fat, not less than 11.5%.
[13] The sum of the percentages of milk fat and total milk solids shall not be less than 33.7%.
[14] Coffee, cereal, special cream.

FEDERAL AND STATE STANDARDS (Continued)

	Sweetened Condensed Skim Milk	Plain Condensed Skim Milk	Dry whole Milk		Nonfat Dry Milk		Plain Ice Cream				
	Total Milk Solids, min %	Total Milk Solids, min %	Milk Fat min %	Moisture max %	Milk Fat max %	Moisture max %	Milk Fat min %	Total Milk Solids, min %	Stabilizer, max %	Weight per Gallon min lb	Food Solids per Gallon min lb
Federal	...	...	...	...	1.5	5.0	...	...	...		..
Alabama	24.0	24.0	26.0	5.0	...	...	10.0	18.0	0.5	...	...
Alaska	...	...	...	5.0	(1)	5.0	10.0	18.0	.5	...	...
Arizona	...	18.0	...	...	...	...	10.0	...	.6	4.5	1.6
Arkansas	28.0	20.0	...	...	(1)	(1)	10.0	18.0	.5	...	1.6
California	...	[2]18.0	26.0	5.0	1.5	5.0	10.0	...	.6	...	1.6
Colorado	...	...	...	...	...	...	12.0	...	...	...	...
Connecticut	...	...	...	...	(1)	(1)	10.0	(3)	.5	4.5	1.6
Delaware	...	...	...	...	...	...	12.0	...	.5	...	...
District of Columbia	...	...	...	...	(1)	(1)	8.0	...	...	...	...
Florida	24.0	20.0	26.0	5.0	...	5.0	10.0	18.0	.5	...	1.6
Georgia	...	...	...	...	(1)	(1)	10.0	...	...	4.5	...
Hawaii	...	...	...	...	(1)	(1)	12.0	18.0	.5	4.5	1.6
Idaho	...	...	...	...	1.5	5.0	12.0	18.0	.5	4.25	1.6
Illinois	24.0	20.0	27.0	5.0	1.5	5.0	12.0	...	...	(4)	...
Indiana	...	...	...	...	1.5	5.0	10.0	18.0	.5	4.25	1.6
Iowa	...	...	...	...	...	...	12.0	20.0	.5	4.5	1.6
Kansas	28.0	20.0	26.0	5.0	...	5.0	10.0	20.0	...	4.5	1.6
Kentucky	24.0	20.0	...	...	(1)	(1)	10.0	18.0	...	...	...
Louisiana	28.0	20.0	26.0	5.0	...	5.0	10.0	20.0	.5	4.5	1.6
Maine	...	...	...	...	[5]1.5	[5]5.0	11.0	(3)	.5	4.5	1.6
Maryland	...	...	...	5.0	(1)	5.0	12.0	20.0	.5	4.5	1.6
Massachusetts	24.0	...	26.0	5.0	...	...	10.0	18.5	.5	...	1.6
Michigan	...	...	...	...	...	...	12.0	(6)	.6	4.5	1.6
Minnesota	24.0	20.0	26.0	5.0	1.5	5.0	12.0	20.0	.5	4.5	1.6
Mississippi	...	18.0	...	...	(1)	(1)	10.0	(7)	.5	4–5	1.6
Missouri	24.0	20.0	26.0	5.0	...	5.0	10.0	20.0	.5	4.5	1.6
Montana	...	20.0	...	5.0	...	5.0	10.0	20.0	.5	4.25	1.6
Nebraska	...	...	...	[8]5.0	(1)	(1)	[9]12.0	[9]20.0	.5	4.5	...
Nevada	...	...	...	5.0	...	5.0	14.0	...	...	4.5	...
New Hampshire	...	...	...	...	...	...	14.0	(3)	.5	4.5	.
New Jersey	28.0	20.0	...	...	...	...	10.0	...	...	...	.
New Mexico	...	20.0	26.0	5.0	...	5.0	12.0	20.0	...	...	.
New York	...	...	...	...	(1)	(1)	10.0	18.0	.5	...	1.6
North Carolina	24.0	20.0	26.0	5.0	...	5.0	10.0	(7)	.5	4.5	1.6
North Dakota	24.0	20.0	26.0	5.0	...	5.0	12.0	...	...	4.5	...
Ohio	24.0	(10)	26.0	5.0	...	5.0	10.0	18.0	.5	4.25	...
Oklahoma	...	...	...	. .	...	5.0	10.0	18.0	.5	4.5	1.6
Oregon	...	...	...	...	. .	. .	[11]10.0	[12]18.0	...	4.5	(7)
Pennsylvania	28.0	20.0	...	...	...	...	10.0	...	.5	4.75	1.8
Puerto Rico	...	. .	...	...	...	5.0			...	...	...
Rhode Island	...	...	...	...	(1)	(1)	10.0	20.0	...	4.5	1.6
South Carolina	...	...	...	...	...	...	10.0	18.0	.5	4.25	1.6
South Dakota	...	...	...	5.0	...	5.0	12.0	(6)	.5	4.5	1.6
Tennessee	24.0	20.0	26.0	5.0	...	5.0	10.0	18.0	.5	...	1.6
Texas	24.0	20.0	26.0	5.0	...	5.0	8.0	...	.5	4.5	...
Utah	...	...	26.0	5.0	1.5	5.0	12.0	(13)	.5	...	1.6
Vermont	...	...	...	...	(1)	(1)	10.0	[3]20.0	.5	4.5	1.6
Virginia	...	...	...	...	(1)	(1)	10.0	20.0	.5	4.5	1.6
Washington	...	18.0	...	5.0	...	5.0	10.0	20.0	...	...	. .
West Virginia	28.0	20.0	26.0	5.0	...	5.0	8.0	18.0	.5	...	...
Wisconsin	[14]28.0	[14]28.0	26.0	5.0	1.5	5.0	13.0	21.0	.5	4.5	1.6
Wyoming	18.0	18.0	...	...	(1)	(1)	10.0	(15)	.5	4.25	1.6

[1] Follow Federal Food and Drug Standards.
[2] Concentrated Skim; milk solids-not-fat, not less than 24%.
[3] Total solids, not less than 36%.
[4] Not more than 100% overrun.
[5] Effective May 1, 1956.
[6] Not less than 0.9 lb per gallon.
[7] Total solids, not less than 35%.
[8] Grade A requirement only.
[9] Tolerance of 0.5% if not constantly below the standard.
[10] Milk solids-not-fat, not less than 20%.
[11] Vanilla only, milk fat, not less than 12%.
[12] Vanilla only, total milk solids, not less than 20%.
[13] Total solids, not less than 28%.
[14] Milk fat, not more than 0.5%.
[15] Total solids, not less than 37%.

FEDERAL AND STATE STANDARDS (Continued)

	Fruit, Nut, or Chocolate Ice Cream, min. %				Sherbet (Milk), %						
	Milk Fat, min. %	Total Milk Solids, min. %	Weight per Gallon, min. lb	Food Solids per Gallon, min. lb	Milk Fat, min. %	Milk Fat, max. %	Total Milk Solids, min. %	Total Milk Solids, max. %	Acid, min. %	Stabilizer, max. %	Weight per Gallon, min. lb
Federal	...	...	...	...	...	...	...	...	...	...	...
Alabama	[1]8.0	18.0	...	1.6	...	2.5	...	[2]8.0	0.35	...	([2])
Alaska	[1]8.0	[1]14.0	...	1.6	...	3.0	...	...	...	0.5	...
Arizona	8.0	...	4.5	1.6	...	...	...	...	...	...	...
Arkansas	[1]8.0	[1]14.0	...	1.6	...	...	4.0	...	.35	...	...
California	8.0	...	...	1.6	...	4.0	...	...	.35	.6	...
Colorado	10.0	...	...	...	...	...	...	...	...	...	...
Connecticut	[1]8.0	([3])	4.5	1.6	...	3.0	([4])	...	.35	.6	...
Delaware	[1,5]8.0	...	...	...	...	...	3.0	5.0	.35	.5	...
District of Columbia	8.0	...	...	...	...	...	3.5	...	.35	...	...
Florida	[1]8.0	[1]14.0	...	1.6	4.0	...	...	...	.35	...	...
Georgia	[5]8.0	...	4.5	...	...	...	...	...	...	...	...
Hawaii	10.0	15.0	4.5	1.6	1.0	3.0	2.0	5.0	.35	.5	6.0
Idaho	[1]10.0	[1]14.0	4.25	1.6	...	...	4.0	...	.35	...	...
Illinois	[1]10.0	...	([6])	...	...	...	...	...	...	1.0	...
Indiana	[1]8.0	[1]14.0	4.25	1.6	...	3.0	4.0	...	.4	...	5.5
Iowa	[7]10.0	[7]16.0	4.5	1.6	...	...	4.0	...	.35	...	...
Kansas	10.0	20.0	4.5	1.6	...	...	...	...	...	...	...
Kentucky	[8]10.0	[8]18.0	...	...	...	1.0	...	5.0	.35	.5	6.0
Louisiana	[1]8.0	[1]16.0	4.5	[9]1.6	2.5	...	...	10.0	.35	.5	6.0
Maine	[1]9.0	([3])	4.5	1.6	1.0	...	([4])	...	.35	...	...
Maryland	[1]8.0	[1]15.0	4.5	1.6	...	...	3.0	5.0	.35	...	4.5
Massachusetts	[1]8.0	[1]16.5	...	1.6	...	...	4.0	...	.35	...	...
Michigan	10.0	([10])	4.5	1.6	...	2.5	...	...	...	...	...
Minnesota	[1]10.0	[1]16.0	4.5	1.6	2.0	...	4.0	...	.4	...	5.5
Mississippi	8.0	([11])	4.5	1.6	...	...	4.0	...	.35	...	...
Missouri	[1]8.0	[1]16.0	4.5	1.6	...	2.5	...	5.0	.35	.5	6.0
Montana	[1]9.0	[1]16.0	4.25	1.6	...	2.0	...	5.0	.35	.5	6.0
Nebraska	[1,12]10.0	[1,12]18.0	4.5	...	...	...	...	8.0	.35	...	4.5
Nevada	12.0	...	4.5	...	2.0	...	...	8.0	...	...	...
New Hampshire	[1]12.0	([3])	4.5	...	2.0	...	...	8.0	.35	.5	6.0
New Jersey	[5]8.0	...	...	...	...	...	...	5.0	.35	...	...
New Mexico	[5]10.0	([5])	...	...	...	...	...	...	...	...	...
New York	[1]8.0	[1]14.0	...	1.6	...	...	...	5.0	.35	.5	...
North Carolina	8.0	([11])	4.5	1.6	...	...	4.0	...	.35	...	...
North Dakota	10.0	...	4.5	...	...	3.0	4.0	...	.35	...	4.5
Ohio	[1]8.0	[1]14.0	4.25	...	...	...	4.0	...	.35	...	...
Oklahoma	8.0	18.0	4.5	1.6	...	...	...	5.0	.35	.6	6.0
Oregon	10.0	18.0	4.5	([11])	...	...	...	...	.35	...	4.5
Pennsylvania	[5]8.0	...	4.75	1.8	...	...	3.0	5.0	.35	.5	4.75
Puerto Rico	...	...	...	...	...	...	...	...	...	...	...
Rhode Island	[1]8.0	[1]16.0	4.5	1.6	...	...	...	8.0	.35	.75	6.0
South Carolina	[1]8.0	[1]16.0	4.25	1.6	...	...	4.0	6.0	.35	.5	4.25
South Dakota	10.0	([10])	4.5	1.6	2.0	5.0	...	...	...	.5	4.5
Tennessee	[1]8.0	[1]14.0	...	1.6	...	...	4.0	...	.35	.5	...
Texas	6.0	...	4.5	...	...	...	...	...	...	...	...
Utah	[1]9.0	([1])([13])	...	1.6	...	...	4.0	...	...	...	...
Vermont	[1]8.0	[3]17.0	4.5	1.6	1.0	...	([4])	...	.35	.5	...
Virginia	[1]8.0	[1]16.0	4.5	1.6	...	4.25	3.0	...	.35	.5	6.0
Washington	10.0	20.0	...	...	...	...	...	...	...	...	...
West Virginia	[8]8.0	[8]18.0	...	...	...	...	...	...	.35	.5	6.0
Wisconsin	11.0	21.0	4.5	1.6	1.0	...	2.0	...	.35	.5	...
Wyoming	10.0	([14])	4.25	1.6	...	3.0	...	10.0	.35	.5	...

[1] Must meet the standard for plain ice cream, except for such reduction as is due to added flavoring ingredients but in no case less than the minimum shown.

[2] Total solids, not less than 30%.

[3] Total solids, not less than 36%.

[4] Total solids, not less than 24%.

[5] Chocolate ice cream must meet the standard of plain ice cream.

[6] Not more than 100% overrun.

[7] Artificially flavored ice cream must meet the standards of plain ice cream.

[8] Before the addition of fruit, nuts, or chocolate.

[9] Fruit ice cream, not less than 1.4 lb.

[10] Total milk solids, not less than 0.9 lb per gallon.

[11] Total solids, not less than 35%.

[12] Tolerance of 0.5% if not constantly below the standard.

[13] Total solids, not less than 26%.

[14] Total solids, not less than 37%.

FEDERAL AND STATE STANDARDS (Continued)

	Frozen Custard					Ice Milk					
	Milk Fat, min. %	Total Milk Solids, min. %	Weight per Gal, min. lb	Food Solids per Gal, min. lb	Egg Yolks per 90 Lb, min. dozen	Milk Fat, min. %	Milk Fat, max. %	Total Milk Solids, min. %	Stabilizer, max. %	Weight per Gal, min. lb	Food Solids per Gal, min. lb
Federal	...	...	...	...	...	...	...	...	...	...	...
Alabama	10.0	18.0	...	1.6	...	2.5	5.0	14.0	...	...	1.3
Alaska	8.0	(1)	...	...	(2)	3.0	8.0	14.0	0.5	...	1.3
Arizona	10.0	...	4.5	...	...	4.0	8.0	...	...	...	...
Arkansas	10.0	14.0	...	1.6	2.5	3.0	10.0	14.0	.5	...	1.3
California	10.0	...	...	1.6	5.0	4.0	...	...	.6	...	1.3
Colorado	...	...	...	...	...	...	12.0	...	...	...	...
Connecticut	[3]10.0	(3)(4)	...	[5]1.8	(6)(15)	3.25	6.0	(7)	.5	...	1.3
Delaware	12.0	...	...	...	5.0	...	...	...	...	...	...
District of Columbia	8.0	18.0	...	1.6	5.0	...	...	...	...	...	...
Florida	10.0	18.0	...	1.6	5.0	3.0	10.0	14.0	.5	..	1.3
Georgia	8.0	...	4.5	...	5.0	...	...	...	...	...	...
Hawaii	12.0	18.0	4.5	1.6	(6)	3.0	5.0	14.0	.5	4.5	1.3
Idaho	Classified as ice milk					4.0	...	14.0	.5	...	1.3
Illinois	...	...	...	...	...	[8]3.0	...	...	[8]1.0	[8]5.0	...
Indiana	...	...	...	...	...	...	...	...	...	...	...
Iowa	12.0	20.0	4.5	1.6	5.0	3.25	6.0	11.0	.5	4.5	1.3
Kansas	...	...	...	...	...	...	10.0	...	...	...	...
Kentucky	[9]10.0	[9]18.0	...	...	...	2.0	3.5	11.0	...	...	1.3
Louisiana	10.0	20.0	4.5	1.6	...	3.5	...	10.0	.5	6.0	1.3
Maine	6.0	(1)	4.5	1.6	(6)	3.25	...	(7)	...	4.5	1.3
Maryland	[10]12.0	[10]20.0	4.5	1.6	(6)	Illegal					
Massachusetts	10.0	18.5	...	1.6	5.0	3.35	10.0	14.0	.5	...	1.3
Michigan	12.0	(11)	4.5	1.6	(12)	...	...	...	...	...	...
Minnesota	12.0	12.0	4.5	1.6	(13)	2.0	12.0	14.0	.5	5.0	1.3
Mississippi	8.0	16.0	4.5	1.6	...	3.0	5.0	(14)	.5	4.5	1.3
Missouri	10.0	20.0	4.5	1.6	(6)(22)	[16]2.0	[16]3.5	[16]11.0	.5	4.5	1.3
Montana	10.0	20.0	4.25	1.6	...	2.0	4.99	11.0	.5	...	1.3
Nebraska	12.0	20.0	4.5	...	5.0	3.0	8.0	12.0	.5	...	...
Nevada	(17)	...	...	..	(18)	4.0	...	...	...	...	...
New Hampshire	14.0	(4)	4.5	...	(6)	...	...	...	...	...	...
New Jersey	10.0	...	...	...	5.0	...	...	...	...	...	...
New Mexico	...	...	...	...	...	...	...	...	...	...	...
New York	10.0	18.0	...	1.6	(6)	...	...	...	...	...	...
North Carolina	8.0	16.0	...	1.6	5.0	4.0	10.0	(7)	.5	4.5	1.3
North Dakota	...	...	...	...	...	4.0	6.0	(19)	...	4.5	...
Ohio	10.0	18.0	4.25	...	5.0	...	...	...	...	...	...
Oklahoma	10.0	18.0	4.0	1.6	5.0	3.25	...	11.0	.5	4.5	1.3
Oregon	...	...	...	...	...	3.2	10.0	14.0	...	4.5	(20)
Pennsylvania	10.0	...	4.75	1.8	(6)	...	...	[21]14.0	...	[21]4.75	[21]1.5
Puerto Rico	...	...	...	...	...	...	...	...	...	...	...
Rhode Island	10.0	20.0	4.5	1.6	(6)	3.25	6.0	11.0	...	4.5	1.3
South Carolina	10.0	18.0	4.25	1.6	5.0	4.0	10.0	12.0	.5	4.25	1.3
South Dakota	12.0	(11)	4.5	1.6	5.0	...	...	...	...	...	...
Tennessee	8.0	14.0	...	1.6	2.5	3.0	10.0	14.0	.5	...	1.3
Texas	...	...	...	...	...	...	...	...	...	...	...
Utah	...	...	...	...	...	4.0	...	(22)	.5	...	1.3
Vermont	10.0	18.0	4.5	(4)	(6)	3.5	6.0	...	.5	4.5	1.3
Virginia	10.0	20.0	4.5	...	(6)(23)	3.25	4.25	11.0	.5	4.5	1.3
Washington	...	...	...	...	...	3.25	...	...	.6	...	...
West Virginia	...	...	...	...	...	...	...	...	...	...	...
Wisconsin	13.0	21.0	4.5	1.6	(6)	3.0	13.0	(19)	.5	...	...
Wyoming	10.0	(24)	4.25	1.6	(13)	3.25	5.5	(7)	.5	4.25	...

[1] Total solids, not less than 33%.
[2] Egg yolks, not less than 2½ doz per 46 lb.
[3] Flavored; maximum reduction 2%.
[4] Total solids not less than 36%.
[5] Flavored; total solids per gallon not less than 1.6 lb.
[6] Egg yolk solids, not less than 1.4%.
[7] Total solids, not less than 30%.
[8] Effective Apr. 28, 1956.
[9] Before addition of eggs.
[10] When fruit, nuts or chocolate is added; milk fat, not less than 8%; total milk solids, not less than 15%; egg yolk solids, not less than 1.0%.
[11] Total milk solids, not less than 0.9 lb per gal.
[12] Egg yolk solids, not less than 1.1%.
[13] Not less than 5 egg yolks per gal.
[14] Total solids, not less than 25%.
[15] When flavored, egg yolk solids, not less than 1.0%.
[16] When semifrozen: milk fat not less than 3.5%, not more than 6.0%; total milk solids not less than 14.0%.
[17] French ice cream: milk fat, not less than 14%.
[18] Egg yolk solids not less than 2.0%.
[19] Milk solids-not-fat, not less than 12%.
[20] Total food solids, not less than 28.0%.
[21] Effective May 8, 1956.
[22] Total solids, not less than 15.0%.
[23] When flavored: egg yolk solids is not less than 1.12%.
[24] Total solids; not less than 37%.

FEDERAL AND STATE STANDARDS (Continued)

	Butter		Cheddar Cheese		Cottage cheese		
					Plain	Creamed	
	Milk Fat, min. %	Moisture, max. %	Milk Fat in Solids, min. %	Moisture, max. %	Moisture, max. %	Milk Fat, min. %	Moisture, max. %
Federal	80.0	...	50.0	39.0	80.0	4.0	80.0
Alabama	80 0	16.0	50.0	39.0	...	...	...
Alaska	(1)	...	(1)	(1)	(1)	(1)	(1)
Arizona	80.0	...	50.0	...	...	4.0	...
Arkansas	80.0	...	50.0	39.0	(1)	(1)	(1)
California	80.0	...	50.0	39.0	80.0	[2]4.0	80.0
Colorado	80.0	16.0	50.0	...	80.0	4.0	80.0
Connecticut	(1)	...	(1)	(1)	(1)	(1)	(1)
Delaware	...	...	...	...	80.0	...	...
District of Columbia	(1)	...	(1)	(1)	(1)	(1)	(1)
Florida	80.0	16.0	50.0	...	...	...	...
Georgia	80.0	...	50.0	(1)	(1)	(1)	(1)
Hawaii	80.0	...	(1)	(1)	(1)	(1)	(1)
Idaho	80.0	...	(1)	(1)	(1)	(1)	(1)
Illinois	80.0	...	[3]50.0	[3]39.0	80.0	4.0	80.0
Indiana	80.0	...	(1)	(1)	80.0	4.0	80.0
Iowa	80.0	...	(4)	...	...	...	...
Kansas	80.0	...	50.0	...	...	...	...
Kentucky	80.0	16.0	50.0	39.0	...	...	...
Louisiana	80.0	...	50.0	39.0	80.0	4.0	80.0
Maine	80.0	...	(1)	(1)	[5]80.0	[5]4.0	[5]80.0
Maryland	(1)	...	(1)	(1)	80.0	4.0	80.0
Massachusetts	80.0	...	(1)	(1)	(1)	(1)	(1)
Michigan	80.0	...	50.0	40.0	80.0	4.0	80.0
Minnesota	80.0	...	50.0	39.0	80.0	4.0	80.0
Mississippi	80.0	...	50.0	39.0	(1)	(1)	(1)
Missouri	80.0	...	50.0	39.0	...	...	...
Montana	80.0	...	50.0	39.0	80.0	4.0	80.0
Nebraska	80.0	...	50.0	38.0	(1)	(1)	(1)
Nevada	80.0	...	50.0	...	...	4.0	...
New Hampshire	80.0	...	(1)	(1)	80.0	4.0	80.0
New Jersey	80.0	16.0	...	...	...	...	...
New Mexico	80.0	16.0	50.0	...	(1)	(1)	(1)
New York	80.0	...	50.0	39.0	(1)	(1)	(1)
North Carolina	80.0	...	50.0	39.0	(1)	(1)	(1)
North Dakota	80.0	...	50.0	39.0	...	...	...
Ohio	80.0	...	50.0	39.0	...	4.0	...
Oklahoma	80.0	...	50.0	39.0	80.0	4.0	80.0
Oregon	80.0	...	50.0	39.0	80.0	[2]4.0	80.0
Pennsylvania	80.0	...	...	...	...	...	...
Puerto Rico	...	...	...	...	...	...	...
Rhode Island	80.0	...	50.0	39.0	(1)	(1)	(1)
South Carolina	...	...	(1)	(1)	(1)	(1)	(1)
South Dakota	80.0	...	50.0	39.0	80.0	4.0	80.0
Tennessee	80.0	...	50.0	39.0	...	...	...
Texas	80.0	...	50.0	39.0	80.0	4.0	80.0
Utah	80.0	...	50.0	39.0	(1)	(1)	(1)
Vermont	80.0	16.0	(1)	(1)	(1)	(1)	(1)
Virginia	80.0	...	50.0	...	(1)	(1)	(1)
Washington	80.0	...	50.0	39.0	...	4.0	...
West Virginia	80.0	...	50.0	...	(1)	(1)	(1)
Wisconsin	80.0	...	50.0	[3]39.0	80.0	4.0	80.0
Wyoming	80.0	...	50.0	39.0	...	4.0	...

[1] Follow Federal Food and Drug Standards.
[2] Partially creamed; milk fat, not less than 0.5%, not more than 2.0%.
[3] With 1.0% tolerance.
[4] Milk fat, not less than 30%.
[5] Effective May 1, 1956.

APPENDIX K

PHS-1783 (SAN)
Rev. 4-53

DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE

PRODUCER DAIRY INSPECTION FORM

Form Approved.
Budget Bureau No. 68-R079.4.

(Inspecting Agency)

NAME

LOCATION

Gallons Sold Daily

Plant

SIR: An inspection of your dairy has this day been made, and you are notified of the violations marked below with a cross (X). Violation of the same requirement on two successive inspections calls for immediate degrading or permit suspension.

COWS

1. Cows, Health:

Tuberculosis control according to Code (a)

Brucellosis control according to Code (b)

Evidence on file (c)

No extensive induration of udders (d)

No cows giving abnormal milk (e)

Other tests as required (f)

Diseased animals removed from herd (g)

MILKING BARN

2. Lighting:

Adequate natural and/or artificial light properly distributed (a)

3. Air Space and Ventilation:

Well ventilated (a)

No overcrowding (b)

4a. Floor Construction:

Floor areas concrete or other impervious and easily cleaned material when required; in good repair (a)

Graded to drain (b)

MILK HOUSE—Continued

8c. Lighting and Ventilation:

Adequate natural and/or artificial light properly distributed (a)

Adequate ventilation (b)

Doors and windows closed during dusty weather (c)

8d. Screening:

All openings effectively screened and doors open outward and self-closing, unless flies otherwise kept out (a)

8e. Miscellaneous Requirements:

Used for milk-handling purposes only (a)

Milk house operations not conducted elsewhere (b)

No direct opening into living quarters or barn except as permitted by Code (c)

Adequate water-heating facilities (d)

2-compartment stationary wash and rinse vats of adequate size (e)

Wastes properly disposed of (f)

9. Cleanliness and Flies:

Floors, walls, windows, shelves, tables, and equipment clean (a)

UTENSILS AND EQUIPMENT—Continued

15. Storage:

Left in treating chamber or bactericidal solution until used or stored properly above floor (a)

Single-service articles properly stored (b)

Equipment and utensils not exposed to toxic substances (c)

Returned milk cans promptly stored (d)

16. Handling:

No handling of milk-contact surfaces after bactericidal treatment (a)

MILKING

17. Udders and Teats; Abnormal Milk:

Milking done in barn or milking parlor (a)

Udders and teats clean (b)

Rinsed with bactericidal solution just prior to milking (c)

Abnormal milk excluded, and properly disposed of (d)

18. Flanks:

Flanks, bellies, and tails of cows clean at time of milking (a)

4. Floor Cleanliness:
Cleaned, as required .... (a)
No swine or fowl .... (b)

5. Walls and Ceiling:
Painted biennially or whitewashed annually or other satisfactory finish .... (a)
Clean; in good repair .... (b)
Ceiling tight if storage overhead .... (c)
Feed room or bins dust-tight with door or cover .... (d)

6a. Cowyard, Grading and Draining:
Graded to drain .... (a)
No pooled wastes .... (b)

6b. Cowyard, Cleanliness:
Cowyard clean and loose-housing areas properly maintained .... (a)
No swine .... (b)

7. Manure Disposal:
Fly breeding minimized by approved disposal methods .... (a)
Stored inaccessible to cows .... (b)

MILK HOUSE

8a. Floors:
Smooth; concrete or other impervious material; in good repair .... (a)
Graded to drain .... (b)

8b. Walls and Ceilings:
Approved material and finish .... (a)
Good repair .... (b)

TOILET AND WATER SUPPLY

10. Toilet:
Provided; conveniently located .... (a)
Constructed and operated according to Code .... (b)
No evidence of human defecation or urination about premises .... (c)
Clean; no direct opening into milkroom .... (d)

11. Water Supply:
Safe sanitary quality (see Code) .... (a)
Adequate in quantity .... (b)
Easily accessible .... (c)

UTENSILS AND EQUIPMENT

12. Construction:
Smooth, heavy-gage material, non-corrodible, surface, non-absorbent, non-toxic, easily cleanable; joints and seams flush .... (a)
Good repair .... (b)
Straining, single-service pads used .... (c)
Small-mouth pails (seamless, if new) .... (d)

13. Cleaning:
Cleaned after each usage .... (a)
Must look and feel clean .... (b)

14. Bactericidal Treatment:
All milk containers and equipment subjected to approved bactericidal process (see Code) .... (a)

19. Milkers' Hands:
No infections on hands or arms .... (a)
Washed; then rinsed with bactericidal solution before milking and upon recontamination .... (b)
Clean and dry while milking .... (c)
Hand-washing facilities, including soap, water, and individual clean towels convenient to milking operations .... (d)

20. Clean Clothing:
Clean outer garments .... (a)

21. Milk stools and Surcingles:
Clean; stored above floor in clean place .... (a)
Stools of easily cleanable construction, no padding .... (b)

22. Removal of Milk:
Immediate removal to milk house or straining room when required .... (a)
Straining done in milk house or straining room, not in barn unless can protected by well-fitting cover and protected from manure and splash .... (b)

23. Cooling:
Milk either cooled to 50° F. or less, or delivered to plant within 2 hours after milking completed .... (a)

24. Vehicles and Surroundings:
Vehicles clean .... (a)
Constructed so as to protect milk .... (b)
No contaminating substances transported .... (c)
Surroundings clean, free from insect breeding and rodent harborages .... (d)

REMARKS:

DATE	SANITARIAN

NOTE.—Item numbers correspond to item numbers for grade A raw milk for pasteurization in Milk Ordinance and Code—1953 Recommendations of the Public Health Service to which please refer.

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PHS-723-1 (SAN)
Rev. 4-53

DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE

PASTEURIZATION PLANT INSPECTION FORM
(Including Receiving Stations)

Form Approved.
Budget Bureau No. 68-R080.4

(Inspecting Agency)

NAME

LOCATION

GALLONS SOLD DAILY	
Milk	
Buttermilk	
Cream	
Other Milk Products	
TOTAL	

SIR: An inspection of your plant has this day been made, and you are notified of the violations marked with a cross (X). Violation of the same requirement on two successive inspections calls for immediate degrading or permit suspension.

1. Floors:

Smooth; impervious; no pools; good repair (a)

Joints between walls and floor impervious (b)

Trapped drains; no sewage backflow (c)

Clean; free of litter and unnecessary material and equipment (d)

2. Walls and Ceilings:

Smooth; washable; light-colored (a)

Clean; good repair (b)

3. Doors and windows:

When flies prevalent, all outer openings effectively screened or otherwise protected (a)

Outer doors self-closing and outward opening (b)

4a. Lighting:

Adequate light (natural, artificial, or both) in all rooms (see Code) (a)

4b. Ventilation:

Sufficient to avoid odors and excessive condensation in structure and on equipment (a)

5. Miscellaneous protection from contamination:

Separate rooms when required [1] (a)

All rooms of sufficient size (b)

Cans of raw milk not unloaded directly into pasteurization room (c)

9. Sanitary Piping:

Smooth, non-toxic, impervious, non-corrodible material, joints flush (a)

Easily cleanable size and design (b)

Good repair; accessible for inspection (c)

Self-draining when assembled (d)

Cleaned-in-place lines meet Code specifications (e)

Minimum length practicable (f)

Pasteurized products conducted therein (g)

10. Construction and Repair of Containers and Equipment:

Smooth, non-toxic, impervious, non-corrodible material (a)

Joints flush (b)

Easily demountable or accessible (c)

Self-draining (d)

Good repair; easily cleanable (e)

Located to facilitate cleaning (f)

No V-type threads in product zone (g)

Pressure-tight seat on submerged thermometers (h)

Close-fitting shaft seals (i)

No lubricant contamination (j)

Single-service articles comply with Code (k)

15. Storage of Caps, Papers, etc.:

Caps, cap stock, parchment paper, single-service containers, gaskets, etc., are purchased in sanitary tubes, wrappings, and cartons, and kept there until used (a)

Stored in clean, dry place (b)

When removed from shipping container stored in suitable cabinet (c)

No contamination during use; no refills (d)

16a.[1] Specifications for Temperature Control Instruments and Devices To Safeguard Pasteurization Process:

Code specifications met by all new indicating and recording thermometers and milk flow-stops, by all replacements, and by recording thermometers under repair which require renewal of tube system (a)

Accuracy and lag specifications met by all existing equipment (b)

16b.[1] Pasteurization by 30-Minute Holding:

(1) Time and Temperature Control of Manual Discharge Systems Equipped for Heating in the Holder:

Adequate agitation throughout holding period, agitator sufficiently submerged (a)

Indicating and recording thermometers on each holder during filling, heating, holding, and emptying (b)

Insects and rodents under control (e)

Protection of product during standardization (f)

Dump vats covered; all openings into equipment and containers protected by covers, flanges, or deflectors (g)

Pasteurized products strained only through perforated metal (h)

No contamination from mezzanine or platforms (i)

Ingredients properly stored and handled (j)

No unapproved products handled (k)

Toxic substances properly handled and labeled (l)

6. Toilet Facilities:

Comply with plumbing code (a)

No direct opening, self-closing doors (b)

Clean; good repair; free from flies (c)

Well lighted; ventilated to outer air (d)

Section 13 posted in all toilets (e)

Hand-washing sign in all toilets (f)

Privies, if used, comply item 10r (g)

7. Water Supply:

Safe: source complies item 11r (a)

Backflow prevented (b)

No connection between safe and unsafe supplies (c)

Adequate; sufficient outlets (d)

8. Hand-washing Facilities:

Hot and cold or warm running water; soap; individual towels (a)

Clean; conveniently located (b)

Wash vats not used for handwashing (c)

Hands washed after visiting toilet (d)

In public sewer or in sanitary manner approved by State Health Authority (a)

Prevention of contamination of milk equipment by sewage backflow (b)

Deflectors for overhead drain lines (c)

Refuse in covered containers (d)

12a. Cleaning of Containers and Equipment:

Containers thoroughly cleaned after each usage (a)

Demountable equipment, other than that effectively cleaned-in-place, disassembled and thoroughly cleaned each day (b)

Other equipment, and in-place pipelines, thoroughly cleaned each day (c)

Cleaned-in-place pipeline record charts complete; on file (d)

12b. Bactericidal Treatment of Containers and Equipment:

Containers treated after each cleaning (see Code) (a)

Assembled equipment treated daily immediately before use (see Code) (b)

Supplementary treatment of equipment not thus reached (c)

Treatment of containers and equipment effective as determined by test 11 (d)

13. Storage of Containers and Equipment:

In clean crates or metal racks above floor; protected from splash, flies, dust, etc.; inverted when practicable (a)

14. Handling of Containers and Equipment:

No handling of product-contact surfaces (a)

No contact of pasteurized products with equipment used for unpasteurized products, and of higher grade products with equipment used for lower grade products, unless such equipment has been given intermediate cleaning and bactericidal treatment (b)

Charts show 143° F. continuously for 30 minutes plus filling time if preheated to 143° F. before entering vat plus emptying time if cooling begun after opening outlet (e)

No product added after holding begun (f)

No raw product by-pass around holders (g)

(2) Time and Temperature Control for Automatic Discharge Systems and Manual Systems Not Equipped for Heating in the Holder:

Meet code requirements (a)

(3) Inlet and Outlet Valves and Connections:

Leak-protector valves of approved design; effective in all closed positions; installed in proper position; good repair; no leakage (a)

All single and multiple-vat installations have leak-protector inlets and outlets except where Code permits disconnection of piping (b)

30-minute tubular holders have leak-protector outlet, or outlet piping disconnected until 30 minutes after filling begun (c)

Inlets and outlets below milk level have close-coupled valves (d)

Plug-type valves have approved stops [2] (e)

Top inlets have air relief if submerged (f)

Valves kept fully closed except inlet while filling and outlet while emptying (g)

Outlet valves given bactericidal treatment before opening if product accumulates in valve passage (h)

(4) Air Space Heating:

Air in holders heated to 5° F. above milk temperature during heating, and kept at 148° F. or higher during holding, by approved device, except as permitted for other products (a)

Approved traps on steam lines (b)

Approved air-space thermometer bulb at least 1 inch above product level; properly located (c)

DATE	SANITARIAN

NOTE.—Item numbers correspond to item numbers for grade A pasteurized milk in the Milk Ordinance and Code—1953 Recommendations of the Public Health Service to which please refer.

[1] Items or parts of items not required for receiving stations.
[2] Required for newly installed equipment.

16—68779-1

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